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AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

(INCORPORATED)

and Petroleum

Vol. 114

PETROLEUM DEVELOPMENT AND TECHNOLOGY

1935

PETROLEUM DIVISION

PAPERS AND DISCUSSIONS PRESENTED BEFORE THE DIVISION AT TULSA, OKLA.,
OCT. 12–13, 1934 AND AT NEW YORK, FEB. 18–21, 1935

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LETTER OF TRANSMITTAL

Mr. A. B. Parsons, Secretary,
American Institute of Mining and Metallurgical Engineers
29 West 39th Street
New York, N. Y.

Dear Sir:

I take pleasure in transmitting herewith TRANSACTIONS, Petroleum Development and Technology, 1935. These papers have been selected from among those presented at the recent meetings of the Petroleum Division held at Tulsa, Los Angeles and New York and are believed to merit publication in this volume because of their lasting interest. Unfortunately, space does not permit the publication of all papers presented at these meetings and a number that appeared in the trade press at the time of the meetings are listed in the Contents with a reference to the publication in which they appeared.

A feature of the New York meeting was a joint symposium with the Institute of Metals Division on The Use of Metals in the Petroleum Industry. The paper of particular interest to the producing branch of the petroleum industry is published herein; the others are mentioned in the Contents.

The presentation of statistical information covering production in a comprehensive form, which was started last year, has been continued and several areas that were missing from Volume 107 appear this year. The preparation of this statistical information represents a great deal of work on the part of those who collaborated, but because of the value of this information to the industry the effort is well worth while.

I wish to take this opportunity to thank the officers and committeemen of the Division, and the officers and headquarters staff of the Institute, for their valuable assistance and advice, which made it possible to carry out the work of the Petroleum Division.

Respectfully submitted,
H. D. WILDE, JR., *Chairman,*
Petroleum Division, 1934.

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PLANS FOR PETROLEUM DIVISION IN 1935

By H. H. Power, Chairman of Division

Plans for the Petroleum Division during the ensuing year are in process of development, in contemplation of the usual fall meetings in the Mid-Continent and California areas, as well as the annual meeting to be held in New York in February, 1936. Houston, Texas has been suggested as the place for the Mid-Continent fall meeting, the exact date to be announced shortly.

During the past year, the Division's technical programs, as in former years, have emphasized the wide fields of engineering endeavor in the petroleum industry yet remaining for more thorough investigation and discussion. An effort has been made to bring an international interest into the proceedings of the Division by inviting the participation of prominent foreign technologists. This viewpoint should promote a continuation in 1935 of past high standards, afford a more thorough understanding of problems throughout the membership, and maintain the Institute's position among the various technical organizations functioning particularly in the oil-producing and refining areas.

In the list of subjects proposed for the fall meetings is the problem of estimating petroleum reserves. Various factors requiring study will include productive sand volume, porosity, average permeability, saturation, and types of recovery. Research papers are proposed dealing with energy consumption per unit of oil recovered, reservoir pressure or energy loss relationship to the usual volumetric method of estimation, and the study of oil and gas segregation within the reservoir.

Other subjects tentatively suggested include new casing practice in relationship to wells producing from several productive zones, progress in lifting methods, repressuring, advanced methods in drilling economies, and the economics of conservation. Although the threat of overproduction yet remains, to a lesser degree than during the past few years, intensive activity is now being directed towards the discovery of new petroleum reserves. This situation undoubtedly will influence, in some considerable degree, the channels through which technical activities will be directed.

A continuation of the commendable work on production statistics for the various oil-producing states and foreign countries has been effected. The usual papers dealing with the general economics of the industry will be reserved for the annual New York Meeting. The Stabilization Committee maintains its membership of nationwide authorities, and interest is manifest in new developments to meet the changing requirements of the industry.

Chapter I. Production Engineering and Engineering Research

Estimation of Petroleum Reserves in Prorated Fields

By Sidney A. Judson,* H. D. Easton, Jr.,† and
W. A. Schaeffer, Jr.,‡ Members A.I.M.E.

(Tulsa Meeting, October, 1934)

Restriction and proration of petroleum production have increased materially the difficulties attendant upon the estimation of reserves, particularly in large, "flush" fields. Such practices preclude the use of decline or other curves, from which, under capacity production conditions formerly prevalent, much could be learned as to the ultimate recovery to be expected from a given field or lease therein. In restricted fields that would produce at many times the low rate allowed by the regulations in force if allowed to flow without restraint, one is forced to use other information than production performance to predict the volume of oil recoverable. Examples are: at Kettleman Hills, California; the Conroe, Van and East Texas fields, Texas; the Iowa field, Louisiana.

It is beyond the scope of this paper to apply a definite method to the determination of the reserves in any actual field, therefore the discussion will be limited to a consideration of available methods and an enumeration of important factors governing the accuracy of such estimates. The problem is to determine not only oil in place but recoverable oil in place, for a given field or tract, which is complex and depends not only on the characteristics of the reservoir but also on the plan of development, the production allocation scheme, the rate of production and many other factors. Many data must necessarily be considered, weighed as to inportance, and assigned quantitative values. Estimates of recovery in prorated fields have been discussed by Brace[1], Shaw[2], Snider[3] and others.

The wide difference in estimates of ultimate recovery from a number of important recently developed fields demonstrates the inadequacy of

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Manuscript received at the office of the Institute Oct. 13, 1934.

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† Petroleum Engineer, Stamey, Easton & Montgomery, Houston, Texas.

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[1] Q. L. Brace: Factors Governing Estimation of Recoverable Oil Reserves in Sand Fields. *Bull.* Amer. Assn. Petr. Geol. (March, 1934) 343.

[2] S. F. Shaw: Should Prospecting for Additional Oil Reserves be Curtailed? *Oil Weekly* (March 12, 1934) 58.

[3] L. C. Snider: A Comparison of Old and New Oil Fields. *Trans.* A. I. M. E. (1933) **103,** 71.

present methods and data. If unlimited time and funds were available for such work, a close approach to accuracy might be possible, but present-day estimates can be only as accurate as the few data available.

Sand Fields

For the purpose of this discussion, a normal sand field is considered to be one in which the sand layers comprising the reservoir are continuous and arched into a closed structure. It may or may not be disturbed by faulting. It will be assumed that the average cross-section of a normal field may be represented diagrammatically as in Fig. 1, and that the productive layers comprising the reservoir are in themselves comparatively homogeneous within the limits of the field. Salt domes may be classified as follows:

A. Piercement domes, in which the salt plug extends within close proximity of the surface and pierces the productive sands on its flanks; e.g., Spindletop dome, Texas.
   1. Super cap-rock sands, or shallow sands overlying the cap rock.
   2. Cap rock proper; i.e., the upper (or calcite) phase of the cap-rock series overlying the salt mass and varying from slight to large porosity.
   3. Flank sands, or sands outside the periphery of the dome proper. Probably the greatest total amount of oil from piercement domes will be obtained from these sands.

B. Deep-seated domes, in which the salt mass is found or indicated at relatively great depths. Production from these domes has been found almost entirely in arched and/or faulted sands above the salt mass; e.g., Iowa dome, Louisiana:

C. Structural fields; e.g. Conroe field, Texas.

Many fields of types *B* and *C* may be considered as normal sand fields, although the sands are more unconsolidated than in most normal fields. Inasmuch as cap-rock (and super cap-rock sand) production on known piercement domes probably has already been well exploited, only the flank sands of such domes will be considered.

Methods for Solving the Problem

In general, possibly only two methods of attack may be used in attempts to solve a problem of this nature.

First Method

Extremely early in the life of a field, virtually only one method is available. *This consists of basing estimates on probable recoveries per acre-foot or other unit volume of reservoir.*

Let it be assumed that layers *A*, *B* and *C* (Fig. 1) are productive, and are distinguishable from one another by lithological, textural or paleontological criteria, or by shale breaks between them. *D* is an impervious stratum above which the reservoir is arched.

It is recommended that the horizon studied be divided into zones of: (*a*) free gas, (*b*) oil with no or little water or free gas, and (*c*) water and oil intermingled. These zones usually will be indicated by drilling, but estimates can be made prior to complete development. It will then be assumed that all of the second named zone (*b*) and all its effective pore space, or the major part of it, is saturated with petroleum, and this zone only will be used in estimating the reserves. Such an assumption seems to be justified by the fact that the oil and gas probably would follow the least resistive channels through the formation until stopped by impervious strata, whereupon high existing pressures would force the oil into the available pore space until all such space was occupied. Beal and Lewis[4] believe that, ordinarily at least, the yield of oil sands is governed more by factors that influence the efficiency of recovery than by an assumed partial saturation. The possible error in assuming this zone to be of 100 per cent effective saturation should be compensated by the fact that there will be some oil recovered from the zone of water and oil intermingled. Convergence maps to show the intervals between the upper surface of each of the layers and the original water level *L-L* should be constructed, and the weighted average intervals determined by obtaining contour areas.

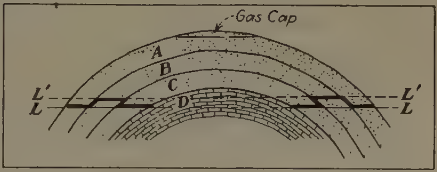

FIG. 1.—GENERALIZED CROSS-SECTION OF TYPICAL NORMAL SAND FIELD.
L-L, original level of oil-water contact.
L'-L', subsequent level of oil-water contact in layer *B*.
Wide black line, oil-water contact at time of estimate.

The volume between the top of each layer and the water, which is the area of the intersection of the oil-water contact and the top of the layer, times the average thickness, may thus be determined, and the volumes of the individual layers found by subtraction. If V is used as a symbol for volume, and V_{TC} is the volume between the top surface of C and the water level, obviously $V_C = V_{TC} - V_D$, and so on for the volume of the other layers. This method should give somewhat more accurate results than sand-thickness maps, contoured on the interval between two irregular surfaces. The average percentage porosities for the layers may have been determined as P_A, P_B and P_C.

Estimation of percentage recoveries, based on reservoir pore space, must be made in the light of experience with similar structures and sands. If drilling and production in these areas were unrestricted, without consideration of the conservation of reservoir energy, it is probable that such recovery percentages may be considered a minimum. Other things being equal, a field in which the production has been restricted, and in which attention has been paid to what are believed to be proper production methods, probably will show an appreciably higher recovery factor than an open-flow field. Therefore, for a field produced under proper control, the recovery per unit of reservoir space should be at least as high as in other fields produced under less favorable conditions.

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[4] C. H. Beal and J. O. Lewis: U. S. Bur. Mines *Bull.* 194.

In using such information from older fields, due weight should be given to the reliability of the available data. Determination of sand content of the reservoir, porosity tests, etc., may have been made less carefully than is required now, so that grave errors might result from using information of unknown dependability. However, the recovery percentage R must be based on some such premise, if nothing better is available.

The recovery per acre-foot for layer A may be estimated as $\frac{43560}{5.61} \times P_A \times R$ bbl., and this result may be multiplied by V_A, expressed in acre-feet (with the possible original gas cap excluded) to obtain the estimated ultimate recovery from that layer. The ultimate recoveries from other horizons may be estimated in a similar manner.

This method is highly approximate, and the result obtained should be regarded as purely tentative. Unknown factors, such as differences in porosity and permeability of productive zones in the field under consideration and the fields with which it is compared, differences in sand thickness, density of development and locating of wells, production rate, etc., may have a profound effect. Perhaps the estimates should be considered only as a qualitative indication of what may actually be the case. In any event, the estimates should be checked periodically as more adequate data become available.

For flank sands around salt domes rough estimates could be based on premises similar to those used for normal sand fields. Detailed geologic studies both of the dome proper and of structural and stratigraphic conditions away from the dome are of major importance in arriving at reasonable and equitable estimates, and such estimates should by no means be considered only an engineering obligation.

The method of computation for flank sands may be as presented above; although, from the nature of piercement domes, additional complexities are present. Each noncommunicating sand should be treated separately, and each radial segment of the sand in question should be treated as a separate reservoir, because radial faulting around piercement domes causes segmentation of flank sands. For a given flank sand a map is made, showing contours on its top; the pattern of faults (usually radial) based on drilling data should be determined also. It is recommended that a minimum of one well in each quadrant be used to determine the peripheral extent of saturated sand. By means of the contour map the inner, outer and peripheral extent of saturated sand may be determined.

For fields not having an effective water drive, the procedure first described may be the only one applicable. However, in such a field, according to Coleman, Wilde and Moore[5], if the initial reservoir pressure, the current average pressure, the solubility of the gas and the average gas-oil ratio from the beginning to the current date are known, it is possible to calculate the fraction of the oil that has been produced. Thus, dividing the cumulative production by this fraction gives an estimate of the total amount of oil originally in the reservoir.

SECOND METHOD

The second method is based on *the relationship of rise in oil-water contact to withdrawals made, and to movement of a possible gas cap.*

If the resistance to movement of fluids is equal in layers A, B and C the rise in water level could be nearly uniform for a certain allocation of per-well allowables. However, most proration plans do not in themselves favor a horizontal rise of water, and experience has shown that rarely is there uniform permeability throughout the producing section.

Let it be assumed that, on the basis of flowing-pressure differential tests, layer B has a decidedly higher degree of permeability than A or C, and that only in B has an appreciable rise of water level occurred. Apparently it would follow that, with the low pressure differentials usually accompanying low production rates, only layer B has yielded a significant quantity of oil from wells that penetrate it, and that essentially all of the oil produced to a given date has come from this stratum, with the exception of oil from wells that do not penetrate it. If the reservoir pressure has been reduced below the pressure at which all the gas originally was in solution, a gas cap also will have resulted.

Thus, if there was no original gas cap, it may be assumed that the oil recovered from all wells penetrating layer B was produced from a sand volume equal to the sum of the volumes of the gas cap and the sand invaded by water. If there was an original gas cap, the oil would have been produced from a volume of sand equal to the volume of sand invaded by water, plus or minus the increase or decrease, respectively, in volume of the gas cap. Let the sand volume invaded by water be represented by V_B' and the volume of or increase or decrease in volume of the gas cap by V_B'', and the oil production from layer B by Y, all in like volumetric units. Then, assuming a continuance of the past conditions and uniformity of porosity, etc., the over-all recovery factor for layer A

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[5] S. Coleman, H. D. Wilde, Jr. and T. V. Moore: Effect of Gas-Oil Ratios on Decline of Rock Pressure. *Trans.* A.I.M.E. (1930) **86**, 174.

could be estimated roughly as $\frac{Y}{V_B' \pm V_B''}$ for increase or decrease, respectively, in gas-cap volume, and per acre-foot as $\frac{43,560}{5.61} \times \frac{Y}{V_B' \pm V_B''}$ bbl. Thus the estimated ultimate recovery for layer *B* could be obtained by multiplying the foregoing by V_B less the original gas-cap volume. For a contracting gas cap, a correction must be made for the loss of the oil that has been forced into the comparatively dry sands of the gas-cap area. Probably only a small percentage of such oil will be recoverable.

Similar procedure may be followed for flank sands in which reasonably accurate determination of water level and gas cap may be obtained.

If no other data are available, the recoveries per unit volume of sand in *A* and *C* must be estimated on the basis of performance of *B*. The estimate for the latter zone may be adjusted in accordance with the differences observed in porosities in the several layers, as determined in the laboratory, and with differences in permeabilities, as evidenced by subsurface flowing-pressure differential determinations.

For *A*, wells on the extreme edge of the field, which penetrated only a very thin section of this zone, and which may have been produced at capacity, or nearly so, may yield valuable information on the basis of their decline. However, even for these wells, the production will have been sustained by the portion of *A* farther up structure, so that their performance cannot be regarded as representative of ordinary capacity production conditions.

Somewhat similar methods may be applied to individual leases, provided the allocation plan permits the oil under a given tract to be produced therefrom. In the majority of instances this will not be entirely true, although some of the present proration plans tend to accomplish it. Thus, for a given lease, after estimating the oil in place, consideration must be given to whether more or less than that volume will actually be produced. If, for example, in East Texas, the density of development on a tract is greater than that of the offset leases and that of the field, and the lease is situated higher than average structurally, it will probably produce materially more than the oil originally in place thereunder.

Important Factors

In the opinion of the writers, the following factors must be determined and given proper consideration in the calculations before even an approximately accurate estimate may be made.

A. Factors Governing Estimates of Oil in Place

1. *Acre-feet of Sand Above Original Oil-water Contact for Each Layer.*—This may be determined as previously set out in this paper. Careful

measurement of the areas enclosed by the various contours will be necessary in order to determine the weighted average intervals or thicknesses.

2. *Reservoir Sand Content.*—As many cores as possible should be made available, preferably from wells situated so as to provide evenly spaced samples of the oil sand. The cores should be subjected to the most careful examination, so that they may be classified as to their content of shale, sandy shale, shaley sand and sand; and so that the various zones in the reservoir may be correlated.

The estimation of "equivalent clean sand" thickness, by which is meant the thickness of a body of clean sand with physical characteristics similar to those of the sand in the reservoir being studied, which would constitute a reservoir of the same capacity as the actual reservoir, composed of sands and sandy shales, is important. In obtaining the thickness of equivalent clean sand it will be necessary to make deductions for sandy shales and shales. These will be found in all degrees of gradation from sands to shales, and the comparatively nonporous shale particles, interspersed through the interstitial spaces between the sand grains, will decrease the porosity of the sand, according to the amount of shale present. It is suggested that the ratio between clean-sand equivalent thickness and the thickness of a sandy shale be considered equal to the inverse ratio of their respective effective porosities.

Various deductions must be drawn from records of drilling action, ditch samples of cuttings, electrical coring, and from the conventional cores themselves, as to what types of material constitute the nonrecovered portions of the intervals cored. From such information, it may be possible to formulate a close estimate of the lithological character of the oil layers in the vicinity of the wells cored, and an average of the results will present a similar picture of the entire reservoir.

In this connection, however, it should be noted that, in general, commercial spacing of wells will not furnish a really adequate number of sampling points, unless there should be an exceptional uniformity of conditions in the reservoir. The error inherent in attempting to formulate a representative average from a comparatively few samples is so great that every effort should be made to obtain as correct an interpretation as possible of the available information.

3. *Sand Porosity.*—The cores should be properly sampled, and porosity determinations made by some accepted laboratory method. Not only the clean sands, but also the shaley sands and sandy shales should be studied, since surprisingly high porosities may be found therein. The information thus made available may be applied to the study of reservoir sand content, and the total pore space in the various strata thus estimated.

The importance of proper sampling of the cores should be emphasized. The sampling should be at intervals as close as is practicable, say 6 in., and the sampling method adopted should be made uniform for all work of this nature. Wide variations in the observed average porosities for the same interval may result from haphazard sampling.

"Effective porosity" has been defined[6] as "the volume of interparticle spaces which communicate with passages of sufficient size to permit the entrance or recovery of gas or oil, expressed as a percentage of the total rock volume." It would appear that the absolute porosity, which is determined by most porosity-determination methods and includes the total of all interparticle spaces regardless of whether they communicate with passages of sufficient size to permit the entrance or recovery (particularly recovery) of gas or oil, would tend to give erroneously high estimates of reserves. Therefore it is believed that only the effective pore space should be considered, although there is in unconsolidated sands practically no difference between the effective and absolute porosities.

The effective porosity may be measured in consolidated sands or sandy shales by any accepted method. For unconsolidated sands, which constitute a major portion of many reservoirs, particularly of flank sands of piercement domes, it will be necessary to make a study of type cores, by screening and by microscopic examination of the texture of the sand and the size and shape of individual sand grains. Where the formations are under enormous pressure, it is possible that a most compact arrangement of the grains will be approached, although the weight of overburden could well be sustained by less compact arrangement. The absolute porosity for spherical sand grains of uniform size, in the most compact arrangement, can be shown to be 25.97 per cent; but there will not be uniform size of grains, neither will they be spherical in shape nor will their arrangement necessarily be the most compact one possible. By means of screening, the uniformity coefficient, defined[7] as the ratio of size of grain that has 60 per cent of the sample by weight finer than itself to the size that has 10 per cent finer than itself, and the "effective size," defined[8] as the size (expressed in terms of millimeters) at the point where 10 per cent of the material by weight is composed of smaller grains and 90 per cent of larger grains, can be determined. It has been found, according to Fettke, that the effective size together with the uniformity coefficient define rather closely the size and uniformity of a sand. The accurate determination of those two factors, therefore, would enable a comparison to be made between consolidated and unconsolidated sands in which those factors are of the same magnitude, whence a more accurate estimate of the effective porosity could be made. For greater refinement in such an estimate the comparative degrees of rounding and of pitting upon the surface of the individual grains should be determined and further corrections made.

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[6] C. J. Coberly and A. B. Stevens: Development of Hydrogen Porosimeter. *Trans.* A.I.M.E. (1933) **103**, 261.

[7] C. R. Fettke: Ten Years' Application of Compressed Air at Hamilton Corners, Pa. *Trans.* A.I.M.E. (1927) **77**, 303.

[8] *Ibid.*

In general, the tendency will be to test only the harder, less porous portions of the clean sands. Often the more porous intervals are soft and unconsolidated, and either will not be recovered by coring or will not be sufficiently indurated to allow sample cubes to be cut therefrom, so that the observed porosities may be somewhat lower than the porosities in what may be the richer portions of a reservoir.

The remarks in section 2 regarding the effect of well spacing on average sand content apply also to the porosities.

4. *Effective Saturation.*—Effective saturation may be defined as the percentage of effective pore space occupied by liquid or gaseous hydrocarbons. For purposes of comparison some indication of the amount of liquid hydrocarbons of comparatively low volatility may be obtained by various methods of extraction, but it is believed that such indications are of little value in estimation of reserves, particularly in unconsolidated sands, as a considerable portion of the contained oil will be lost during the process of removing the sample from its formation.

B. Factors Influencing Recovery

1. *Sand Permeability.*—Inasmuch as a rock may be highly porous and yet not yield fluid, the determination of relative permeabilities of the various sand members is of prime importance. It seems to be generally recognized that, other things being equal, the strata having the highest relative permeabilities will give up their contents most freely, and will have a somewhat higher ultimate recovery per unit volume of reservoir.

Permeability tests of properly sampled cores may be made in the laboratory, and a general conception of the permeabilities may thus be had. Perhaps even more important are tests run in the field. The Schlumberger method of "electrical coring" gives considerable data on effective porosity and the contents of the sand. Subsurface flowing-pressure differential tests are of great value in this connection. Obviously, a layer producing at a given rate, or through a range of rates of flow, with a small loss in pressure in the well bore opposite the layer, is more permeable than if the pressure loss were greater. Differentiation between the permeabilities of various horizons may be obtained in this manner.

2. *Oil-water Contact.*—The elevation at which the original oil-water contact intersected the upper surface of the reservoir often is closely determined by dry holes and oil wells drilled in proximity to the horizontal limits of production. Several exploratory wells might be intentionally

drilled to water early in the life of the field, in order to delimit the contact as accurately as possible. The use of the so-called "Water Witch" and the Schlumberger method will probably be indispensable in this connection. This is basic information of an exceedingly important kind, and upon it may depend the accuracy of an entire estimate. Therefore it is well worth while to consider some additional expenditures, other than those ordinarily incurred, to make the same available.

The oil-water contact may or may not have been at the same elevation in the various members of a reservoir, and separation thereof by impervious material makes it highly probable that the contact is not continuous.

This applies also to the contact at a period later in the life of a field, as it is more probable that differences in level will exist then than when the pool was virgin. It is important that a series of accurate determinations of these contacts be made. Upon the precise knowledge of water levels at various times during the earlier life of a field may depend, to a very considerable degree, the accuracy of forecasts of future performance.

3. *Gas-oil Contact.*—The limits of an original gas cap (if present), and the progress of expansion or contraction of an original or subsequent gas cap, should be determined with all possible exactness. Such information will have a bearing on recovery estimates similar to that of the movement of the oil-water contact.

4. *Physical Characteristics of Oil and Gas.*—The specific gravity and viscosity of the oil should be known; likewise the specific gravity of the gas, its solubility in the oil, and the solution ratio at the pressures prevailing in the productive layers.

The "shrinkage factor," or ratio of the volume occupied by a unit of oil at the surface to the volume occupied by the same unit, with its dissolved gas, in the reservoir, should be ascertained. The solubility, solution ratio, and the shrinkage factor may be determined in the laboratory from bottom-hole samples.

Compressibility of the fluids in the reservoir may play an important part in their expulsion therefrom. Comparison of movement of the oil-water and gas-oil contacts with the fluid volume recovered may give an insight into this.

5. *Gas-oil Ratio.*—It is highly desirable that accurate records be kept of gas-oil ratios, so that some idea may be obtained of the efficiency of production methods used, and so that the cumulative and current withdrawals of fluid from the reservoir may be determined.

6. *Reservoir Pressures.*—Periodical, systematic surveys of static subsurface pressures, referred to a common datum, will prove valuable in determining pressure decline, which is one of the important factors determining the flowing life of a field. The surveys will afford information as to the rate at which the reservoir energy is being dissipated. A knowledge of the rate of pressure decline will assist in the determination

of the effect of gas wastage on ultimate recovery. Adequate subsurface pressure data will allow deductions to be made regarding the movement of fluids in the reservoir, and additional data on relative permeabilities may thus be afforded.

Of especial importance in flank sands of piercement domes is the presence and intensity of a sustained hydrostatic head, as evidenced by subsurface pressures. Without a sustained water drive, it has been found that sustained production from the highly tilted flank sands will not be obtained. In addition to the driving effect, a highly advantageous action of "flushing" is obtained by water movement. The presence and magnitude of hydrostatic head can readily be determined by the engineer; the probability that the head will be sustained can best be determined by the geologist.

7. *Capillary Retention and Retention by Adhesion of Oil to Sand Grains.*—According to Uren and El-Difrawi[9], the capillary retention of petroleum by sand varies directly as the surface tension of the oil, directly as the cosine of the angle of contact of the liquid on the mineral composing the sand, inversely as the density of the oil, inversely as the 2.3 power of the porosity of the sand, and inversely as the size of the sand grains.

Except for the angle of contact, which is indeterminable by present methods, these governing factors can be measured and estimates made of the quantity of oil retained by this capillary action. The amount of oil retained by adhesion to sand grains will be inversely proportional to the size of the grains and directly proportional to the surface tension of the oil, and should be readily calculable.

8. *Ultimate Number of Wells and Location Thereof.*—Attention must be given to the ultimate number of wells required to complete the development program for a field under consideration. The stage in the life of a field at which drilling is completed is also significant. Little is definitely known, from actual results obtained, of the quantitative effects of density of well spacing on ultimate yield but, other things being equal, moderately wide spacing may well result in recoveries greater than with inordinately close spacing, as has been pointed out by Suman[10]. Too close spacing may increase operating costs to such a degree that premature abandonment of wells, with a consequent loss of oil, could result; as is well known, increasing the number of holes drilled into a given reservoir does not increase the contents thereof.

A given number of wells suitably placed on a structure may have more favorable effects on ultimate recovery than the same number of wells located at random. Versluys[11] has enumerated a number of principles governing the location of wells on a structure. If possible, no wells except exploratory holes should be drilled in a gas-cap area.

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[9] L. C. Uren and A. H. El-Difrawi: Capillary Retention of Petroleum in Unconsolidated Sands. Petr. Dev. and Tech. in 1926, 70. A.I.M.E.

[10] J. R. Suman: The Well Spacing Problem—Low Well Density Increases Ultimate Recovery. *The Oil Weekly* (May 28, 1934) 43.

9. *Rate of Production and Proration Scheme.*—It is generally agreed that an unduly high rate of withdrawal from a field may result in a serious waste of reservoir energy, both in the form of gas and hydrostatic head, and under such circumstances drainage as complete as might be effected with proper production control will be highly improbable.

The method of allocation of production may have a considerable part to play in the yield from a field. Complete unitization of the working and royalty interests is as nearly as possible the ideal condition for distributing the withdrawals so as to conserve the available energy to a maximum extent. Any proration scheme that permits the blowing off of gas from a gas cap will result in a considerable loss of oil, which will be forced into the gas cap and probably will not be completely recovered therefrom.

The effect of a proration scheme on the recoverable reserve of a field is secondary, however, to its effect on the recoverable reserves for individual leases, which may be profound. For example, in East Texas, where proration is on a total potential basis, the ultimate recovery for a given lease depends to a large extent on the density of development thereon and its structural position, rather than on the oil in place under the tract.

SUMMARY

A group of factors affecting estimates of reserves in sand fields in which production has been restricted has been presented, together with possible applications of some of them. The list of factors is not complete, but it is believed that the most essential ones are included. It is recommended that further studies be made of these pertinent items and their effects upon the factor of recovery and that attempts be made to apply definite weight to each of them.

No pretense is made that absolute accuracy may be obtained in such estimates. There are altogether too many interfering influences at work to permit this. However, investigation of available data may often permit close approximations to be made. The principal governing factors that would limit accuracy of estimates by the methods discussed are the number and location of wells drilled to the horizons concerned and the number of data obtained from each well. More extensive coring, aided by electric coring methods, will assist greatly in zoning productive horizons. Well surveying is of major importance in obtaining accurate geological concepts of the dome and flank sands.

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[11] J. Versluys: Principles Governing the Location of Wells with Respect to Structure. *Proc.* World Petr. Congress, London, 1933.

The cost of obtaining the information necessary for adequate estimates, other than that normally experienced, will depend largely upon the refinement of recovery factor and should not be considered as being in the nature of additional costs, since such refinement furnishes necessary data for the determination of more favorable rates of production.

Undoubtedly, future developments will allow estimates of this nature to be made with considerably greater precision than is now possible. Accurate estimation of reserves is vital to the determination of proper development and operating practice, or to equitable unitization, and the progress of unitization as a policy may well be marked by an accompanying improvement in this phase of engineering.

DISCUSSION

(*L. A. Ogden presiding*)

P. P. Gregory,* Iraan, Texas.—I am sorry that this paper did not include limestone reservoirs under restricted production. It appears that the rate of decline in reservoir pressure plotted against cumulative production of oil might give a good idea of the expected future recovery. In the Yates pool, we plot reservoir-pressure points on vertical axis against corresponding cumulative production on the horizontal axis. All points fall on a straight line on semilogarithmic paper. This straight line is then projected to a predetermined pressure point at which the natural flow should cease, and the expected flush production is read on the horizontal axis opposite that point.

D. L. Katz,† Bartlesville, Okla.—I should like to speak in favor of the method used by Coleman, Wilde and Moore[12]. Their method uses gas and oil production data, bottom-hole pressures and temperatures, and physical properties of the hydrocarbons. It does not use porosities and the usual geological factors.

M. Lee,‡ Wichita, Kansas.—This is a matter that is coming to be important; production figures are figures of exhaustion. There are two schools of thought on the subject and the application of the proper or most accurate method of estimation is worth serious study. Proration, being one of the several necessary evils of the oil industry under its extremely competitive operation, causes much false information to be disseminated in regard to the values of producing properties.

Those who have used the pressure decline and time factors, so long relied upon when 100 per cent production was taken, will find they greatly overestimate total recovery per acre, of prorated fields when the actual recovery has been found. The same rule will not accurately apply as to pressure in fields with gas and oil that have a very low rate of allowable, as many large wells have in flush fields. Low rate of withdrawal permits water-drive fields to slowly readjust the pressure drop, caused by withdrawal of the reservoir content, which fails to show the usual pressure decline, either in time produced or in the usual comparative depletion that large 100 per cent withdrawals would show.

Potentials, although taken at regular periods under uniform conditions, fail to indicate the true depletion the production has caused, especially when the fields are prorated to 5 to 15 per cent of potential. Any greatly increased withdrawal, either on lengthened potential or higher percentage of allowable, quickly shows the falsity of estimating recovery on potentials of short duration or in fields where very low allowables have prevailed. The past experience of barrels per acre for total recovery is much more dependable for an estimated total recovery than any estimates based on prorated "potentials." The natural initial production of wells is much more dependable than the grossly exaggerated potentials, obtained in lime producing fields after acid treatment.

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* Proration Petroleum Engineer, Yates Pool.

† Phillips Petroleum Co.

[12] Reference of footnote 5.

‡ Petroleum Geologist.

The rate and height of the oil column "fill up" in wells being drilled on prorated fields is a valuable and much more accurate index of expected recovery than any potential. The use of natural initial production, with a decline curve based on the "fill-up" of subsequently drilled wells in prorated fields probably comes nearest to accurate bottom-hole pressure comparison. When new field wells no longer have any appreciable fluid column or fill-up on completion, the prorated field has reached a comparative stage of depletion of a field that has had 100 per cent market as a method of exhaustion and, regardless of its well's book record of high remaining potentials, its actual daily production is much nearer 100 per cent than the producers care to admit. The practical end of the fill-up of new wells in any field should not be construed as an exhausted reservoir. It may be approximately 80 per cent depleted and have a long life as a field of small recovery.

Investors in leases or royalty would be wise to have their investments recommended by competent persons not using the potential as the only means of estimating total recovery, and also to ascertain the length of time and under what rules the potential is determined.

MEMBER.—Did Mr. Gregory take the rate of water encroachment—the change in gas-oil ratio—in his method?

P. P. GREGORY.—This method can be applied only to fields devoid of the water drive. The variation in the gas-oil ratio is a disturbing factor. In order to have a definite relationship between the cumulative production of oil and the decline in reservoir pressure, the gas-oil ratio must remain constant or should fluctuate but slightly. The curve I referred to represents a production period of seven years.

H. H. POWER,* Tulsa, Okla.—The situation in the Kansas siliceous lime areas permits the use of potential-cumulative curves for purposes of reserve estimating. By actual test, only 28 cu. ft. of gas per barrel of oil was found in one well at Chase, this representing the amount in solution at reservoir pressure. Potential-cumulative curves show a uniform decline before encroaching water captures the well. Thereafter, a new slope is usual, and by careful extrapolation the remaining reserves can be approximated with a fair degree of accuracy.

C. E. TURNER, Bartlesville, Okla.—In gas-drive fields, we should use the percentage of energy expended at different dates and different accumulated production instead of bottom-hole pressure. An abandonment pressure would have to be estimated. This energy curve could be constructed for different abandonment pressures using the past production, bottom-hole pressure and solubility data. Then, from this percentage energy curve, and knowing the bottom-hole pressure, the percentage of the ultimate recovery that has been obtained can be estimated.

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* Petroleum Engineer, Production Dept., Gypsy Oil Co.

Influence of Well Diameter upon the Pressure Gradient and Rate of Flow of Oil through the Reservoir Rock in the Vicinity of a High-pressure Flowing Well

By L. C. Uren,* Member A.I.M.E., J. Domercq, Jr.,† and J. Mejia‡

(New York Meeting, February, 1935)

That the diameter of a well through the oil-producing formation has an important influence on its rate of production is a principle accepted by many petroleum technologists. Knowledge of this principle extends back at least to the time when Slichter and King[1] confirmed it in a study of the dynamics of flow of water through porous strata into wells. More recently, the senior author[2] and his associates[3] have produced qualitative experimental data confirming the principle as applied to drainage of expanding oil and gas mixtures, and suggesting that wells of large diameter, or wells having cavities about them within the reservoir rock, enjoy a material advantage in competition with wells of ordinary diameter. Apparently, however, no one has produced experimental data designed to indicate quantitatively the advantages that wells of large diameter possess in comparison with wells of normal diameter producing under comparable conditions. This paper reviews some preliminary experimental results of this kind, together with some conclusions and speculations based thereon, which further emphasize the importance of well diameter as a factor in determining the efficiency of oil recovery.

Theoretical Aspects of Radial Flow of Fluids into Wells

It is well understood that in a reservoir rock of uniform thickness and permeability oil and gas flow toward the wells along radial lines. The cross-section of the reservoir rock through which the fluids must move becomes ever smaller as the wall of the well is approached. The velocity of flow must therefore correspondingly increase, an effect that is accentuated by the rapid increase in volume of the fluid due to release

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† Los Angeles, California.

‡ Bogota, Colombia, S. A.

[1] Slichter and King: U. S. Geol. Survey 19th *Ann. Rept*, (1897–98) pt. 2.

[2] L. C. Uren: Increasing Production of Petroleum by Increasing Diameter of Wells. *Trans.* A.I.M.E. (1925) **71,** 1276–1300.

[3] L. C. Uren, F. F. Davis and W. L. Jarvis: Advantages of Large Diameter Wells in Exploitation of Oil Fields. *Bull.* Amer. Petr. Inst. (Jan. 3, 1929) **10,** No. 2, 94–105.

of gas from solution, and expansion that results from rapid reduction of pressure in the vicinity of the wall of the well. The changing cross-section of flow may be represented diagrammatically as in Fig. 1. Here *ABCD* represents a square inch on the wall of a well 6 in. in diameter, and segment *ABCDEFGH*, parallel with the bedding planes of the productive formation, represents the prism of oil-reservoir rock that yields the total volume of oil and gas passing through the square inch on the wall of the well. *IJKL* is the area intercepted by this prism on the walls of a concentric 60-in. well. We may think of this theoretical wedge-shaped prism of oil-reservoir rock as a drainage unit or element, the entire production of the well being derived from a number of such units, which make up the total thickness and expanse of reservoir rock surrounding the well.

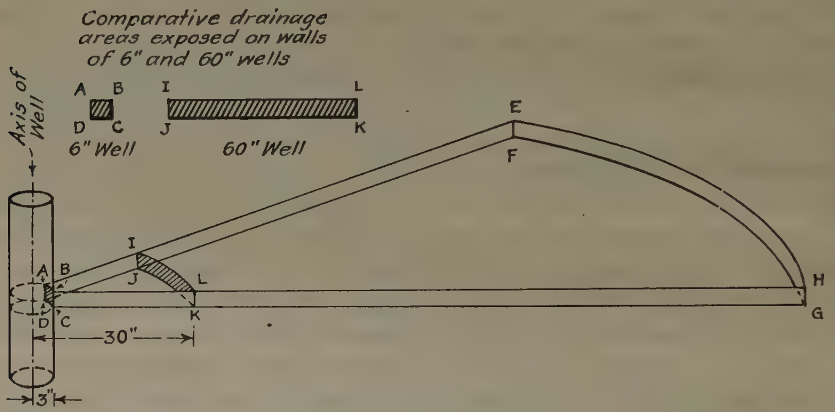
Comparative drainage areas exposed on walls of 6" and 60" wells
Axis of Well
A
B
D
C
6" Well
I
L
J
K
60" Well
E
F
I
A
B
J
L
H
D
C
K
G
30"
3"

FIG. 1.—CONCEPT OF "DRAINAGE UNIT" AND RADIAL CHARACTERISTICS OF FLOW THROUGH RESERVOIR ROCK TOWARD WELL.

It has been demonstrated that the resistance offered by a porous rock to flow of fluids through it is directly proportional to the rate of flow[4]. It follows, therefore, that near the wall of a well, where flow is comparatively rapid, the rock resistance and pressure loss is considerably greater than at points remote from the wall of the well, where the velocity of flow is very low. In the theoretical drainage element referred to above, at the wall of a well having a radius of 3 in. where the cross-section of the reservoir rock is but 1 sq. in., the rate of flow would be at least 10 times that at a cross-section 30 in. back in the reservoir rock from the axis of the well. The ratio of 10 to 1, cited for the relative flow velocities at the assumed distances from the axis of the well, would hold true if we were dealing with a fluid of constant volume; but where the volume of fluid is constantly increasing because of gas expansion, it is clear that an even greater ratio of relative velocities would apply.

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[4] W. O. Smith: Capillary Flow through an Ideal Uniform Soil. *Physics* (September, 1932).

LABORATORY APPARATUS EMPLOYED

The experimental results presented herein were secured with the aid of an apparatus that closely reproduces all of the physical conditions existing within the reservoir rock about a high-pressure flowing well. This apparatus has been in use over a period of several years in the Petroleum Engineering Laboratories of the University of California and has been described in detail in an earlier paper[5]. It will be sufficient here to describe it only in general terms, with the expectation that one interested in securing dimensional and other details will find them in the earlier paper to which reference is given.

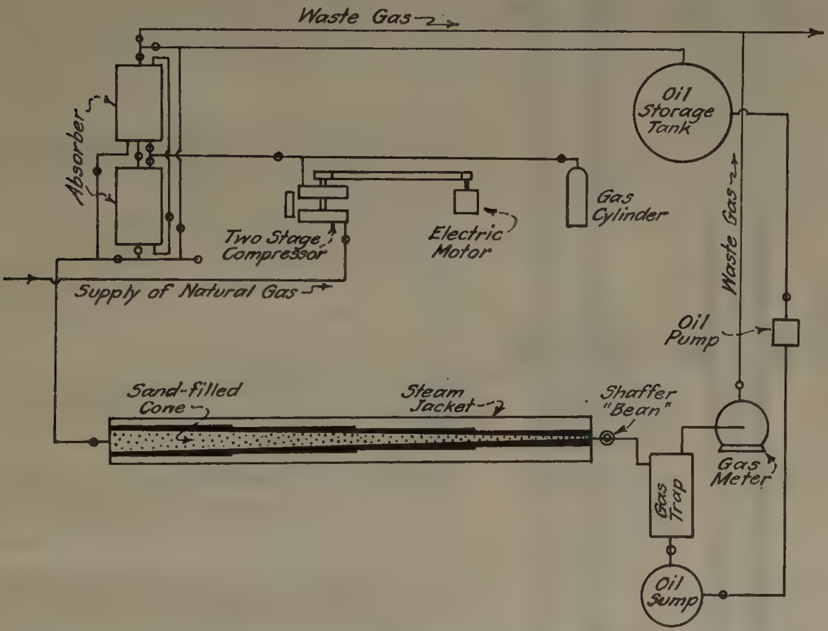

FIG. 2.—DIAGRAMMATIC "FLOW SHEET" SHOWING RELATIONSHIP OF PARTS OF CONICAL DRAINAGE APPARATUS.

The apparatus permits of making tests with gas-saturated oils under formation pressures as great as 2000 lb. per sq. in., and with rates of flow comparable with those in wells producing several thousand barrels of oil per day. Fig. 2 presents a diagrammatic outline of the several parts of the apparatus.

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[5] L. C. Uren and E. J. Bradshaw: Experimental Study of Pressure Conditions Within the Oil Reservoir Rock in the Vicinity of a High-pressure Producing Well. *Trans.* A.I.M.E. (1932) **98,** 438–466.

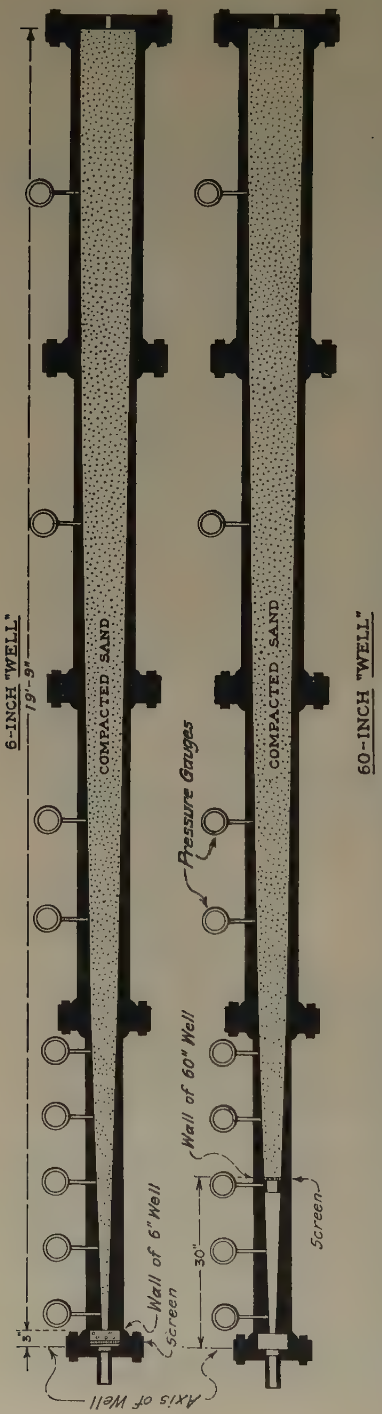

Fig. 3.—Longitudinal sections through drainage cone showing it as used in experiments simulating flow into a 6-in. well and as used in experiments simulating flow into a 60-in. well.

Manipulation of Apparatus in Conduct of Tests

Two series of tests were performed under comparable conditions, except that in one group of experiments the drainage cone was completely filled with sand, so that it was, in effect, producing through the wall of a well 6 in. in diameter. In the second group of experiments, the screen confining the sand within the tube was set 2½ ft. from the delivery end of the cone and the sand removed on the downstream side, so that delivery was, in effect, through the wall of a well 60 in. in diameter. Fig. 3 presents two longitudinal sections of the drainage cone, showing the position of the sand body within, for each of the two series of tests.

In each of the two series of experiments, tests were made with several different "formation" pressures. In some experiments, herein referred to as "sustained flow tests," the test pressure was maintained at the large end of the cone and flow maintained with a constant rate of delivery of oil at the discharge end until equilibrium pressure conditions throughout the sand column were attained. In other experiments herein referred to as "closed-flow tests," the sand column was charged with gas-saturated oil at the desired "formation pressure." Then the inlet valve at the large end was closed, the outlet valve at the small end was opened and the oil allowed to escape under the influence of the expansive force of the gas released from solution. In each experiment, the pressure gradient along the cone was determined by observation of pressure gages connecting at short intervals directly with the sand column. Also, the rate of flow was recorded for each sustained flow test, and in closed-flow tests the rate of flow and cumulative production were recorded at brief time intervals.

The oil used in these tests was a California asphaltic-base crude of 24° A.P.I. gravity, having a viscosity of 0.30 poises at 65° F., the prevailing temperature at which the tests were conducted. The surface tension at this same temperature, as measured with the Du Noüy tensiometer, was 32.3 dynes per centimeter. The gas used in saturating the oil was Kettleman Hills natural gas from which the readily condensable fractions had been extracted. Its composition was approximately 78 per cent methane and 22 per cent ethane. The sand used was a Monterey beach sand having the grain-size distribution indicated in Table 1, and it was compacted in the cone to an approximately uniform porosity, averaging 32.8 per cent.

TABLE 1.—*Results of Screen Analysis of Sand*[a] *Used in Experiments with Conical Drainage Apparatus*

MESH[b]	PERCENTAGE	CUMULATIVE PER CENT
On 10	0.04	0.04
10– 14	0.07	0.11
14– 28	6.14	6.25
28– 35	21.46	27.71
35– 48	39.76	67.47
48– 65	29.20	96.67
65–100	2.51	99.18
100–200	0.54	99.72
Through 200	0.25	00.97

[a] Uniformity coefficient, 2.00; "effective" grain size, 0.05 mm.

[b] Using Tyler standard screens.

The reservoir sand has high permeability and the oil is of perhaps average viscosity among California crudes but of relatively high viscosity in comparison with most Mid-Continent and Eastern crudes. In comparison with most reservoir rocks encountered in the field, the factors entering into our conical-tube experiments undoubtedly present a condition of abnormally high permeability. We should, therefore, expect field drainage efficiency to be much less perfect, pressure gradients in the vicinity of wells in the field considerably more abrupt and the differences in these and other respects between wells of small and large diameters to be emphasized to a greater degree under field conditions than in the experimental apparatus.

COMPARISON OF PRESSURE GRADIENTS IN SUSTAINED-FLOW TESTS

Sustained-flow tests were performed under conditions simulating flow into both 6-in. and 60-in. wells. Experiments were made with sustained basal pressures at the large end of the cone, ranging from 200 to 1400 lb. per square inch. In one series of tests, "dead" oil (i.e., oil containing no, or very little, dissolved gas) was used and in another series, "live" oil saturated with dissolved gas at the pressures maintained was employed. Space does not permit of a complete record of the many tests made, but typical selections are offered from assembled data for comparative purposes. For the convenience of the reader, they will be presented in graphic form.

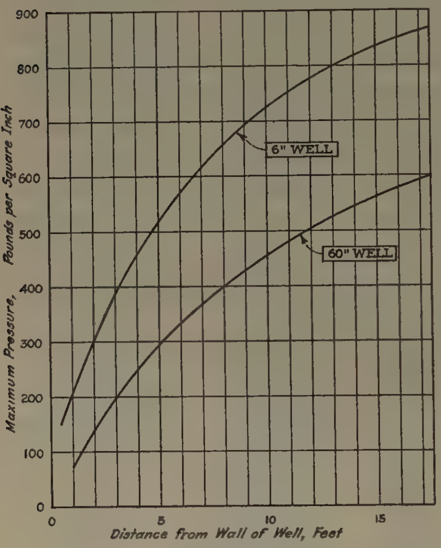

FIG. 4.

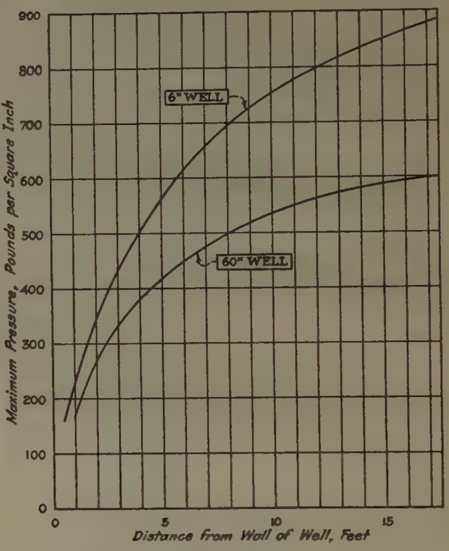

FIG. 5.

FIG. 4.—COMPARATIVE PRESSURE GRADIENTS FOR EQUAL RATES OF SUSTAINED FLOW. Sustained flow of dead oil at rate of 1256 c.c. per minute.

FIG. 5.—COMPARATIVE PRESSURE GRADIENTS FOR EQUAL RATES OF SUSTAINED FLOW. Sustained flow of live oil at rate of 1296 c.c. per minute.

Fig. 4 presents two pressure gradients secured in experiments using "dead" oil, each obtained in the same rate of flow, one for a 6-in. well and the other for a 60-in. well. The established rate of flow was maintained in the 60-in. well, with a differential pressure between the two ends of the cone of 600 lb. per sq. in., while in the 6-in. well a differential pressure of 862 lb. was necessary. The gradient created about the small well was considerably steeper than that in the vicinity of the 60-in. well. Fig. 5 presents two additional pressure gradients obtained with "live" oil, one for a 6-in. and the other for a 60-in. well. Again, the 6-in. well gradient is considerably steeper than that created by the 60-in. well, and a differential pressure nearly 300 lb. greater was necessary to maintain the recorded flow of 1296 c.c. per minute.

Pressure gradients with live oil are invariably steeper in the vicinity of the wall of the well than when dead oil is used, whether the diameter of the well is large or small. Fig. 6 presents typical comparative gradients for both live and dead oil obtained with the 60-in. well at two different

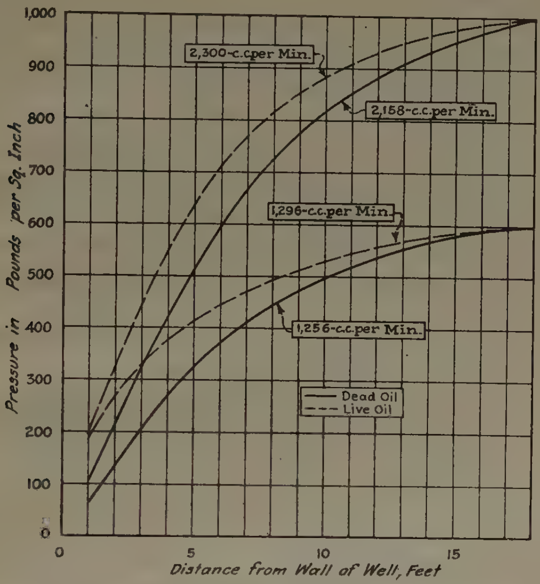

FIG. 6.—COMPARATIVE PRESSURE GRADIENTS FOR DEAD AND LIVE OIL AT TWO DIFFERENT RATES OF FLOW.

basal pressures; for a given basal pressure, somewhat more live oil flows than dead oil. The steeper gradients obtained with live oil are due, of course, to the greater volume of fluid in motion and higher flow velocities resulting from release of gas from solution in the oil.

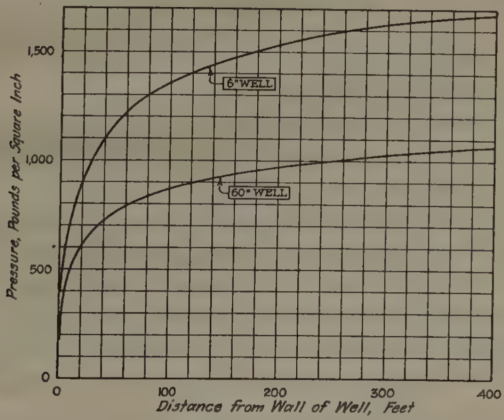

FIG. 7.—COMPARATIVE PRESSURE GRADIENTS FOR EQUAL RATES OF SUSTAINED FLOW. Sustained flow of live oil at rate of 1296 c.c. per minute.

Extrapolation of the two pressure gradients presented in Fig. 5 yields the graphs reproduced in Fig. 7. These afford an interesting basis for comparison of the approximate drainage influence developed under the experimental conditions presented in the 6-in. and 60-in. wells. For example, it is shown that at a distance of 300 ft. from the axis of a 6-in. well the formation pressure necessary to maintain a flow of 1296 c.c. per minute would be more than 600 lb. greater than that necessary to maintain the same rate of flow over a similar distance to a 60-in. well. Stated another way, a formation pressure of 1000 lb. per sq. in. is capable of maintaining a flow at the rate of 1296 c.c. per minute over a distance of 250 ft. toward a 60-in. well, but the same pressure is capable of moving the same quantity over a distance of only 30 ft. toward a 6-in. well. For movement of oil at this rate over a radius of 350 ft., the 6-in. well requires about 58 per cent greater pressure than the 60-in. well.

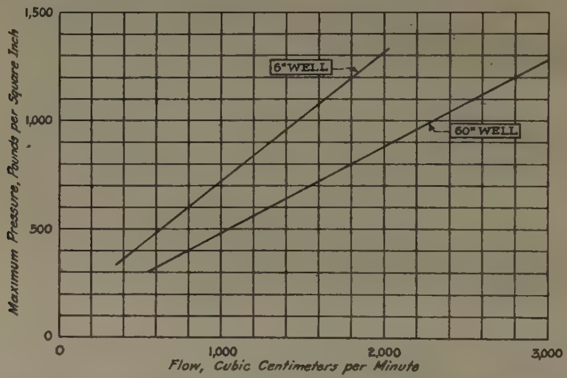

FIG. 8.—COMPARATIVE RATES OF FLOW AT DIFFERENT BASAL PRESSURES, WITH LIVE OIL IN SUSTAINED FLOW.

It should perhaps be explained that the extrapolated gradients reproduced in Fig. 7 imply a reservoir condition in which the oil is undersaturated with dissolved gas at distances more than 17½ ft. from the wall of the well, there being no gas released from solution except within 17½ ft. of the wall of the well. While such a condition would seldom be true in the field, it is believed that the extrapolated graphs are not greatly divergent from the usual field condition, inasmuch as the volume of gas released from solution and existing in the formation as such at pressures above 500 lb. per sq. in. is comparatively small. In any event, the two extrapolated gradients are subject to approximately the same corrections and therefore are comparable.

COMPARISON OF RATES OF FLOW IN SUSTAINED-FLOW TESTS

Under a given basal pressure, the 60-in. well invariably yields from 145 to 150 per cent more dead oil than does the 6-in. well under comparable conditions. This figure accords very closely with the rate of flow indicated as probable by a modified form of the original Slichter equation[6] proposed in a paper by the senior author[7] in 1924. This formula indicates that the rate of production varies inversely as the logarithm of the ratio of the total distance traversed by the oil in its movement through the reservoir rock, divided by the radius of the well. Fig. 8 presents two graphs based on experimental data, with the aid of which the rate of flow of live oil into either size of well under any specified pressure may be readily predicted.

Again, as noted above, it has been observed that the rate of flow of live oil is greater, for a given basal pressure than the rate of flow of dead oil, though this is less noticeable with the 6-in. than with the 60-in. well. This confirms a conclusion reached in some of the earlier work with this apparatus, that gas bubble resistance to movement through the pore spaces of the reservoir rock is a force of comparatively small magnitude and does not seriously retard flow. At least, it may be said that any retarding influence that the gas bubbles may have is more than offset by the reduced density and resistance to movement (viscosity?) presented by the mixture of gas bubbles and oil, in comparison with the density and viscosity of gas-free oil.

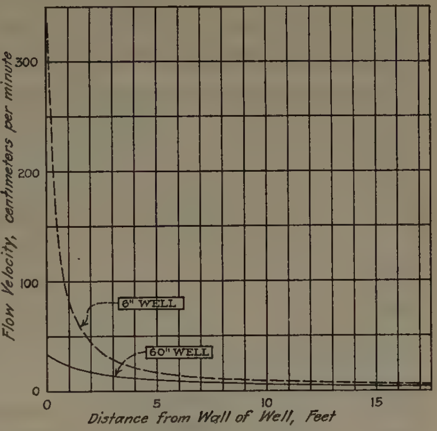

Fig. 9.—Comparative flow velocities of dead oil at different distances from the wall of the well, for equal rates of flow.

The reason for the greater rate of flow into the well of larger diameter under given differential pressure is apparent when we consider the relative flow velocities at different distances from the wall of the well, as represented graphically in Fig. 9. For dead oil, the rate of flow at the wall of a 6-in. well is necessarily 10 times that at the wall of a 60-in. well. Ten feet or more back in the sand from the wall of the well there is comparatively little difference in flow velocities. If the flow resistance increases directly as the rate of flow—as is probable with the rates of flow with which we are here concerned—it may be shown that for a given volume-rate of flow the resistance offered by the reservoir rock within 2¼ ft. (30 in. minus 3 in.) of the wall of a 6-in. well is greater than the resistance offered by the reservoir rock within 200 ft. of the wall of a 60-in. well.

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[6] Reference of footnote 1.

[7] Reference of footnote 2.

If large volumes of gas are flowing with the oil through the reservoir rock, it is apparent that flow velocities will be materially greater than those indicated for dead oil in Fig. 9. Computation of the rate of flow and resistance offered by flow of gas-oil mixtures through sand is fraught with considerable uncertainty, the rate of release of gas from solution with reduction of pressure, and the amounts of gas flowing at different distances from the wall of the well, being somewhat problematical.

ULTIMATE RECOVERIES IN CLOSED-FLOW TESTS

A few closed-flow tests were performed to determine the influence of well diameter on ultimate recovery. In these tests, as previously explained, the pores of the sand are charged with gas-saturated oil and the inlet valve at the larger end of the tube is then closed. When the outlet valve is opened, the oil expelled is produced only by the expansive effects of such gas as is present in solution in the oil. Because it offers less resistance to flow, the larger diameter well invariably produces a greater total or ultimate volume of oil than the small well. Fig. 10 presents production graphs showing the cumulative recoveries obtained in comparable tests in which an initial pressure of 600 lb. per sq. in. was used. After making due allowance for free oil in the apparatus outside of the sand body, it appears that the total recovery secured by the large well was more than twice as great as that secured by the small well. Yet the volume of oil-saturated sand connected with the large well was smaller than that with the small well. Computations based on the total pore space of the sand body available for storage of oil, and the gross recovery after exhaustion of the gas, indicate a percentage recovery of only 8.1 per cent for the 6-in. well and 17.6 per cent for the 60-in. well. The large diameter well thus not only enjoys a greater current rate of recovery but is more efficient in the sense that it secures a materially greater ultimate recovery.

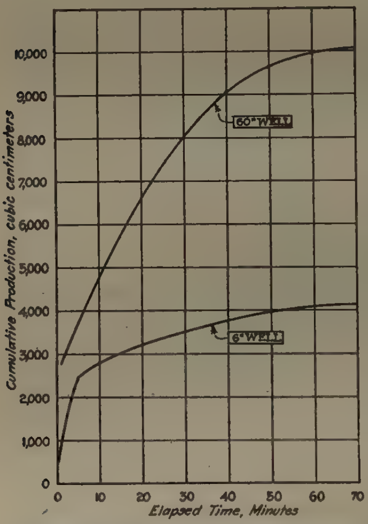

FIG. 10.—COMPARATIVE CUMULATIVE PRODUCTIONS IN CLOSED FLOW OF LIVE OIL WITH INITIAL PRESSURES OF 600 LB. EACH.

Though gas-oil ratios were not determined with accuracy in these tests, it is clear that the 60-in. well produces with materially lower gas-oil ratios than the 6-in. well. For example, in the gradients of Fig. 5, inasmuch as the basal pressure necessary to maintain the rate of flow of 1296 c.c. per minute through the experimental cone is some 280 lb.

greater for the 6-in. than for the 60-in. well, the entering oil, if saturated, would contain about 60 cu. ft. more of gas per barrel. Aside from a higher formational gas-oil ratio, it also seems probable that there would be more "slippage" of gas through the oil in the small well. This is evidenced by the materially lower percentage recovery secured with the 6-in. well than that obtained by the 60-in. well in the closed-flow tests. In so far as gas-oil ratios may be taken as a measure of recovery efficiency, it is clear that the advantage is again with the well of large diameter.

Practical Realization of Advantages of Large Diameter

Though it is not the purpose of this paper to discuss in detail the practical means by which the advantages of large-diameter wells may be realized in field practice, it seems appropriate to briefly review the methods by means of which the authors believe that such advantages could be substantially obtained. Obviously it would be uneconomic, in some cases impractical, to drill from the surface deep wells of 60 in. or more in diameter. The same advantages may be realized, however, by drilling wells of normal diameter and then developing cavities of 5 ft. or more in diameter about them within the reservoir rock. In hard rocks, this may be accomplished with the aid of explosives. The advantages to be derived from "shooting" wells are well known. The authors believe that the larger rates of production, the lower gas-oil ratios[8] and the greater ultimate recoveries obtainable from wells that have been shot[9] is in no small part due to the formation of cavities about them.

In semiconsolidated and unconsolidated reservoir rocks, the same result may be achieved by hydraulic methods, and to some extent also by special types of mechanical under-reamers. That the hydraulic system of forming cavities about wells within the reservoir rock and of filling them with gravel—a system proposed by the senior author[10] in 1924—is practical, has recently been proved by the successful completion of a number of deep gravel-wall water wells by this method[11]. In a typical case, a well drilled for water near Sumter, S.C., to a depth of 600 ft., was reamed near the bottom by hydraulic jets and 190 cu. yd. of gravel was introduced, also by hydraulic methods, to fill the cavity thus formed. The well produces more than twice as much water as other wells of normal diameter drilled only 200 ft. distant and producing from the same stratigraphic horizon. Furthermore, the well with the gravel-filled cavity produces no sand, which is troublesome in the surrounding wells, the gravel serving as a perfect filter or screen. There would appear to be no reason why this same result could not be achieved in any oil well producing from unconsolidated or semiconsolidated formations, and at any desired depth.

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[8] S. F. Shaw: Increasing the Ultimate Recovery of Oil. *Trans.* A.I.M.E. (1931) **92,** Petr. Dev. and Tech., 176–193.

[9] L. C. Uren: New Methods of Using Energy in Gas to Stimulate Oil Recovery. *Nat. Petr. News* (Apr. 27, 1927) 67–77.

[10] Reference of footnote 2.

[11] R. R. Schweitzer: Gravel-Wall Wells. *Jnl.* Amer. Water Works Assn. (June, 1934) **26,** No. 6, 712–724.

Petroleum engineers have made important progress in other ways in improving recovery efficiency, but comparatively little effort has been made as yet to control this most important factor of well diameter. We go on year after year, drilling small-diameter wells, apparently content with a result that obviously could be greatly improved. Practical ways must be found to secure the substantial advantages that go with large-diameter wells. More may be accomplished in improving recovery efficiency in this way than by any other. It is the one avenue that yet remains to be explored in achieving the highest possible ultimate recovery by well-drainage methods. Fewer wells, lower development cost, lower production cost, more efficient utilization of the natural expulsive forces, greater per-well-per-day yields and greater ultimate recoveries and per-acre yields: all are possible by drilling wells of larger diameter.

Conclusions

Consideration of the experimental results and theoretical considerations presented in this paper would seem to justify the following conclusions:

1. The pressure gradient in the vicinity of a large-diameter well is less abrupt than in the vicinity of a small-diameter well, and the pressure at a given distance from the wall of the large well will always be materially lower, under otherwise comparable conditions, than at the same distance from the wall of the small well.

2. Irrespective of the diameter of the well, the pressure gradient is more abrupt in the immediate vicinity of the well when gas accompanies the oil than when gas is absent. The gradient becomes steeper as the differential pressure and gas-oil ratio increase. However, the differences between "live" oil and "dead" oil in these respects are less with large diameter wells than with small.

3. Extrapolation of experimental pressure gradients for 6-in. and 60-in. wells indicates that large-diameter wells develop a materially greater drainage radius under a given field pressure than small-diameter wells. More energy is consumed in moving the oil through the zone within 27 in. of the wall of the 6-in. well than through a zone 200 ft. in radius about the wall of a 60-in. well.

4. The rate of production of a 60-in. well producing dead oil under a given set of reservoir conditions is nearly 1.5 times that of a 6-in. well under similar conditions. Any flowing or pumping well should enjoy

a comparable increase in productivity at any time during its productive life by increasing its diameter from 6 to 60 inches.

5. The rate of flow of live oil under a given pressure differential is greater than for dead oil under the same differential pressure. Large-diameter wells apparently enjoy a greater advantage in this respect than small-diameter wells. Such resistance as gas bubbles in association with oil offer to movement through the reservoir rock is apparently more than offset by the reduced density and viscosity of the gas-oil mixture, so that the net effect of the gas is to promote rather than to curtail drainage.

6. Large-diameter wells secure a larger ultimate recovery than small-diameter wells under otherwise comparable conditions. Under the experimental conditions in closed-flow tests, the 60-in. well secured more than twice as great a percentage recovery as the 6-in. well. The percentage recovery increases as the initial pressure increases, relatively more so with large-diameter wells than with small-diameter wells.

7. Large-diameter wells produce with lower gas-oil ratios than small-diameter wells.

8. The advantages that go with large-diameter wells may be realized practically by forming cavities about them within the oil reservoir rock. In hard, well cemented reservoir rocks this may be accomplished with the aid of explosives; in unconsolidated or semiconsolidated sands and sandstones, by mechanical reamers or by hydraulic methods, filling the cavities thus formed with gravel to prevent caving and serve as a sand filter or screen. Recent applications in the conditioning of water wells show the hydraulic method to be entirely practical.

9. The oil-reservoir rock in the immediate vicinity of the wall of a producing oil well is a critical zone in which much of the energy utilized in moving the oil through the reservoir rock into the well is consumed. A high degree of conservation of formational gas energy may be achieved by moderate increase in the well diameter, removing the part of the formation that consumes so large a part of the natural energy associated with the oil. By this means the efficiency of oil recovery may be increased materially, wells may be more widely spaced and development and production costs greatly reduced.

Colloidal Properties of Clay Suspensions

By W. K. Lewis,* Lombard Squires* and W. I. Thompson*

(Tulsa Meeting, October, 1934)

Clays consist predominantly of hydrated silicates of alumina. The formula is frequently assumed to be $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$, and certain of them undoubtedly have substantially this composition, but in general the ratio of silica to alumina is considerably higher. However, they always contain water of chemical constitution, as shown by Table 1.

Table 1.—*Composition of Clays*[a]

Analysis	Percentages						
	I Crude Kaolin	II Washed Kaolin	III Ball Clay	IV Fireclay	V Adobe	VI Gumbo Clay	VII Bentonite
SiO_2	62.40	45.78	46.85	51.92	58.19	38.08	50.30
Al_2O_3	26.51	36.46	33.15	31.64	11.19	11.36	15.96
$Fe_2O_3 + FeO$	1.14	1.36	2.04	1.13	2.77	2.60	0.86
$CaO + MgO$	0.58	0.54	0.75	0.47	12.96	23.70	7.77
$K_2O + Na_2O$	0.98	0.25	0.71	0.40	0.18	2.18	2.64
H_2O	8.80	13.40	16.45	13.49	2.00	3.06	23.61
Moisture	0.25	2.05				18.80	
SO_3			0.3				
TiO_2				1.16	1.05	0.7	
CO_2					8.00	(18.80)	
Al_2O_3/SiO_2	0.254	0.49	0.44	0.379	0.1195	0.1852	0.197
CaO/Na_2O	1.017	3.71	1.82	2.02	61.5		5.08

I. North Carolina. Low plasticity.
II. Same as I, after washing. Low plasticity.
III. Tennessee. Good plasticity.
IV. Pennsylvania flint fireclay. Low plasticity.
V. Laredo, Texas. Very plastic. CaO/Na_2O corrected for CO_2.
VI. San Antonio, Texas. Fine grained, highly plastic. Moisture and CO_2 were determined together at 18.8 per cent.
VII. Selected crude bentonite, California.

[a] Data from H. Ries: Clays. John Wiley & Sons, New York, 1927.

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The behavior of clays is largely determined by the properties of the individual clay particles, most important of which are size, shape and surface characteristics. There is little doubt that plastic, claylike properties are not developed until the particle size is below about 0.01 mm. The lower limit is not known, although the existence of particles as small as 2 by 10^{-6} cm. in diameter has been reported. Clays also contain appreciable percentages of particles larger than 0.01 mm., usually considered as impurities, silt, sand, etc. Because of their size, below the resolving power of the microscope, the shape of the particles is difficult to determine. Several observers have reported the presence of flat, platelike crystals in clay when examined microscopically. Whether this is true of all clays is not known, but facts point to the conclusion that even the small particles may be platelike. Thus, most bentonite suspensions show double refraction when flowing in viscous motion, indicating that the particles are anisotropic. Furthermore, many of the typical clay minerals are shown microscopically to occur as plates or bunches of plates. Pure kaolin exhibits a marked X-ray pattern, showing the presence of crystalline particles. From this evidence it may be inferred that clays are composed largely of exceedingly fine, platelike crystals of the "clay" minerals, contaminated with varying amounts of sand, organic matter and the like.

This paper is concerned primarily with the behavior of clay suspended in water. Under these conditions the clay particles possess appreciable electric charge, as shown by their migration in an electric field. Under almost all conditions the charge is negative. It is possible to "plate" out the particles on a suitably prepared electrode, building up layers of considerable thickness. The magnitude of the charge per particle varies widely and the charge can be neutralized and even reversed, particularly by polyvalent cations. The particles are so small that, while not resolvable by the microscope, they can be seen to exhibit Brownian movement in considerable degree. However, for the production engineer, the most important properties of aqueous suspensions of clays are their characteristics from the point of view of flow and gelation. Hence the following discussion will be directed almost exclusively to a study of these problems, but in order to understand them it is necessary to have a clear picture of the behavior, not merely of clay suspensions, but of other types of fluids as well.

DETERMINING VISCOSITY

The best way to determine the viscosity of a pure liquid is the use of some form of capillary viscosimeter. If, however, such an instrument is employed for suspensions, or solutions of materials of high molecular weight, difficulties are frequently encountered, probably due to irregularities of flow caused by the fact that the particles themselves have dimensions approaching that of the diameter of the capillary. In such cases a viscosimeter of the falling ball or concentric cylinder type is advantageous, since the thickness of the liquid layer is far greater; the latter has the further advantage that it can be operated with rates of shear that are approximately the same at all points in the fluid. All instruments of this type measure the torque at some rate of rotation, the viscosity being proportional to the twisting force and inversely to the rate of rotation.

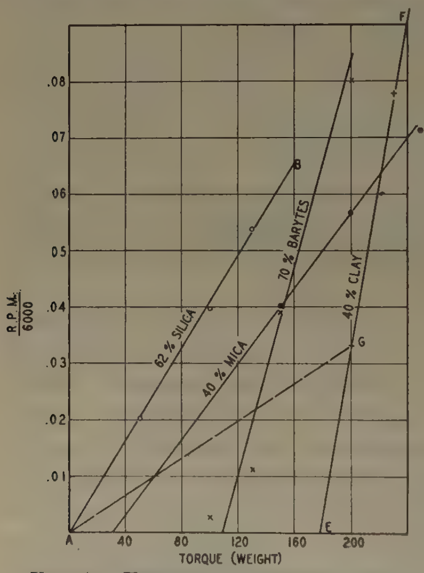

FIG. 1.—EFFECT OF FINE GRINDING ON VARIOUS AQUEOUS SUSPENSIONS. CONCENTRATIONS IN WEIGHT PER CENT.

If, in such a torsion viscosimeter, the rate of rotation is varied, in testing all pure liquids and many solutions, even of high molecular weight solutes and suspensions, the torque is proportional to the rate of twist; i.e., to the revolutions per minute. However, many suspensions and colloidal solutions show an entirely different behavior in that, if torque is plotted against revolutions per minute the line no longer passes through the origin, although the relationship is substantially linear, but if extended below the experimental range, to zero r.p.m., cuts the torque axis at a different point.[1] This is called yield point of the fluid. Possession of a yield point thus determined may well be taken as a criterion of plasticity.

It is clear that for a fluid with zero yield point the slope of the r.p.m.-torque curve is inversely proportional to its viscosity; i.e., directly proportional to its fluidity. For a fluid showing a yield point, the fluidity for a given rate of shear is proportional to the slope of the line connecting the point in question with the origin; for instance, on Fig. 1, for the fluid represented by the line *EF*, at the point *G*, the fluidity is the slope of the dotted line connecting *G* with the origin. The diagram shows that the viscosity of the fluid represented by the line *EF* is changing progressively and rapidly with the r.p.m.; i.e., with the rate of shear. Because the slope of the r.p.m.-torque line is a measure of the fluidity for fluids with zero yield point, Bingham has suggested that in other cases the corresponding slope be called the mobility. For fluids with zero yield point, fluidity and mobility become identical. Study of the diagram makes it clear that for fluids exhibiting yield point the mobility is the fluidity (i.e., the reciprocal of the viscosity) of the fluid for conditions of infinite rate of shear.

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[1] Discussion of the actual behavior of the fluid in the immediate neighborhood of zero rate of shear is beyond the compass of this article.

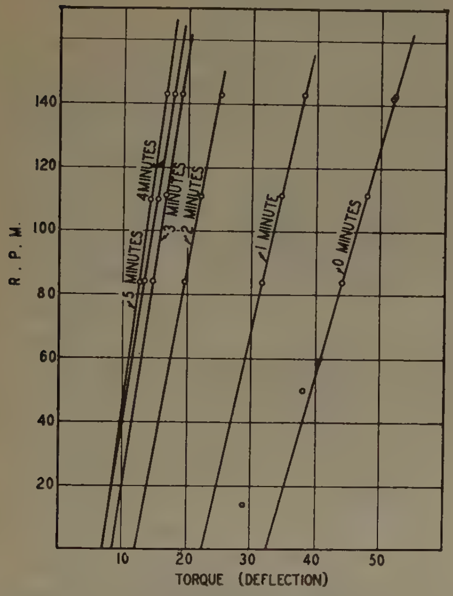

Fig. 2.—Effect of high-speed stirring on Conroe drilling mud.

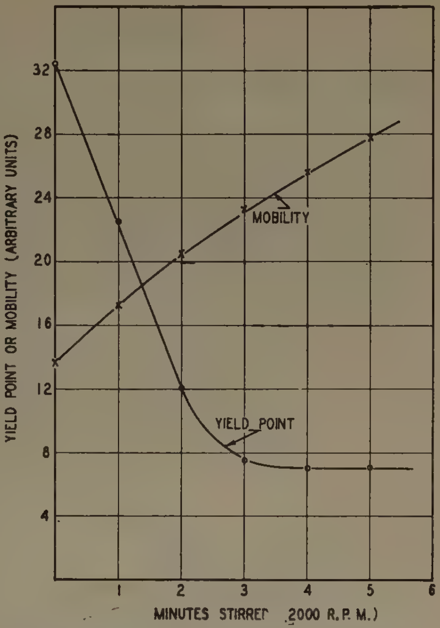

Fig. 3.—Effect of high-speed stirring on Conroe drilling mud.

Postulate a suspension of particles of definite volume, unchanging with rate of shear. From the analysis on which the Einstein equation discussed below is based, the viscosity should be constant, independent of rate of shear.

Fig. 1 shows data on the r.p.m.-torque relation as determined with a Stormer viscosimeter for: (1) a suspension of finely ground quartz in water, suspensions of (2) barytes and (3) mica similarly prepared, and (4) a suspension of a typical china clay. The quartz exhibits no detectable yield point, the mica and barytes both show a yield point, unmistakable even though small, whereas the clay is characterized by a very high yield point value. Fig. 2 shows the influence on the viscosity behavior of the clay of

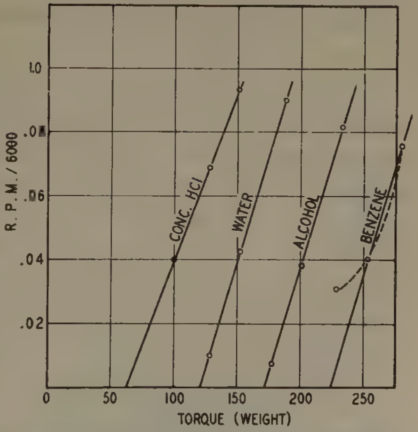

Fig. 4.—Effect of type of suspending liquid on clay suspensions.
Concentration of clay = 60 grams per 100 c.c. of liquid.

violent agitation immediately prior to testing. Curves 1 to 6 correspond to times of preliminary agitation of 0, 1, 2, 3, 4 and 5 minutes, respectively. While one minute greatly decreases the yield point, longer agitation produces progressively less effect. The agitation also increased the mobility, but far less than the change in yield point. These changes can be visualized more readily from Fig. 3. Fig. 4 shows the influence on clay suspensions all containing identical quantities of clay per unit volume, of the character of the suspending liquid. Clay suspended in 95 per cent alcohol shows a mobility practically the same as that of the clay suspended in the water, but its yield point is approximately 50 per cent higher. Concentrated hydrochloric acid decreases the mobility slightly but pulls the yield point down to approximately half that of water. The suspension in benzene does not show a linear relationship but the fluidity is even less than that of alcohol. The effect of small amounts of addition agents to aqueous suspensions is seen from Figs. 5, 6 and 7, each of which was constructed from a large

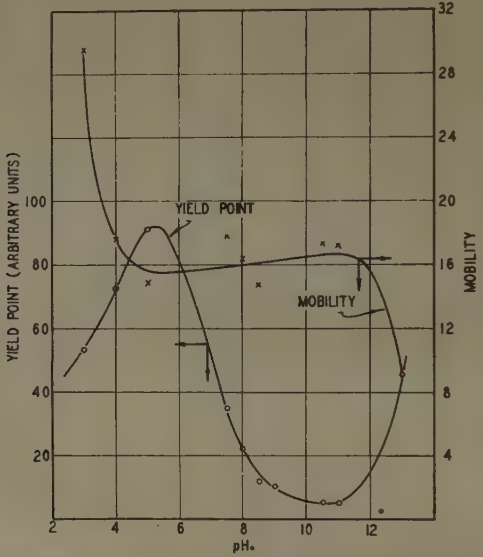

Fig. 5.—Effect of pH on yield point and mobility of Conroe drilling mud.

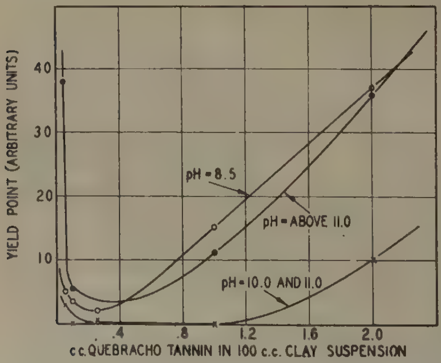

Fig. 6.—Effect of Quebracho tannin on yield point of Rabbs Ridge drilling mud at various pH values.

number of lines similar to those of Fig. 3. The mud of Fig. 7 is not identical with that of Figs. 5 and 6.

Causes of Viscosity Relationships

The problem in hand is to develop the clearest practicable picture of the underlying causes of these relationships.

Mathematical analysis shows that the viscosity of a dilute suspension of rigid, spherical particles, uniform in size, is given by the Einstein equation, $\mu = \mu_0(1 + 0.5v)/(1 - v)^2$, in which μ_0 is the viscosity of the liquid in which the particles are suspended, μ the viscosity of the suspension, and v the volume fraction of the suspended particles. The viscosity of the suspension is, as the equation indicates, independent of the size of the particles and rate of shear. The relationship has been carefully tested experimentally and undoubtedly is sound. Furthermore, the influence of variation in particle size in a given suspension is not great provided the fractional size distribution remains unchanged, and, while the equation breaks down at high values of v, it still remains true that at these high values the viscosity is a unique function of the volume fraction. There is no doubt that the high viscosity shown by ordinary suspensions is due solely to this Einstein effect; i.e., to the volumetric interference of the suspended particles with the movement of the liquid. Furthermore, the same is true of the viscosity of emulsions of one liquid in another; in other words, the interfering, suspended particles need not be rigid. The resistance to deformation of a small droplet caused by its surface tension is ample to give the effect. There is every reason to believe that this same volumetric interference of suspended particles is the fundamental cause of the high viscosity exhibited by so-called colloidal solutions of many materials of extremely high molecular weight, although in this case, as will appear later, other important factors enter into the phenomenon. Finally, it is important to recognize that, while the shape of the suspended particles has but little effect so long as their dimensions are roughly the same in all directions, rodlike or chainlike particles produce viscosity increases in excess of the solvent out of all proportion greater in relation to the volumetric fraction of the particles.

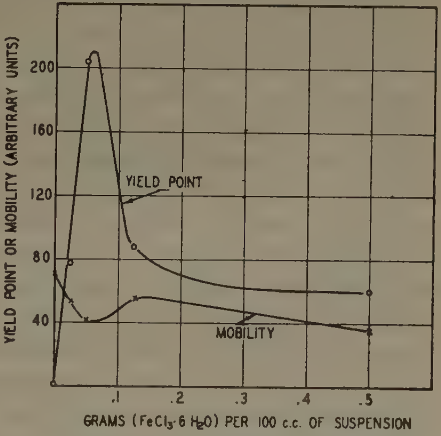

Fig. 7.—Effect of ferric chloride on Rabbs Ridge mud.

Assume a suspension in a given liquid of particles of definite, unchanging volume. From the preceding discussion it is clear that the viscosity should be constant, independent of rate of shear. Consequently, one is forced to the conclusion that in suspensions or colloidal solutions in which the relation between r.p.m. and torque is other than a straight line through the origin, some factor other than the volumetric interference of the suspended particles with liquid flow is playing a predominant part. These abnormalities in behavior can be explained only in the light of the knowledge of the surface characteristics of the particles and their interactions with each other.

Study of the characteristics of liquids has led to the conclusion that molecules exhibit attractive forces which are enormous in magnitude in the immediate neighborhood of the molecular surface, but fade away with extreme rapidity as the distance from the surface increases. Furthermore, these attractions undoubtedly are electrical in character, of the nature of stray fields of electric force caused by incomplete neutralization of the electronic charges (e.g., of the valence forces) within the molecule. Their total effect in any given case is proportional to the amount of surface involved and to the intensity of the stray fields in the neighborhood of that surface. It thus becomes possible to understand the influence of molecular weight on boiling point. A molecule on the surface of a liquid is held there by the attractive forces under discussion. Clearly, the larger the molecule, the greater the extent of its surface, and hence the greater the force holding it on the surface of the liquid. Its escaping tendency into the vapor is due predominantly to its kinetic vibrations, which in turn depend primarily on the temperature, uninfluenced by the structure or size of the molecule. Volatility is determined by the balance between these two sets of forces. Hence, as molecular weight and therefore molecular surface increases, volatility always decreases greatly. However, one must not ignore the intensity of the surface forces. Thus, water boils at a far higher temperature than methane, despite almost identical molecular weights. This is because the intensity of the fields of force around the methane molecule is low, whereas around the water molecule it is high. In other words, the former is inert and nonpolar, whereas the latter is active and highly polar. This point of view is fully confirmed by the chemical and physical characteristics of the two compounds. A similar approach offers a clear, qualitative explanation of the viscosity characteristics of pure liquids and of the behavior of liquids in general.

These attractive forces in the neighborhood of the molecular surface are capable of holding together not only similar, but also dissimilar molecules. Because of them there is undoubtedly a high degree of loose combination or association of the molecules of solvent and solute, particularly with solutions in polar liquids. This is the phenomenon sometimes called solvation. It explains the well recognized hydration of electrolytes in aqueous solutions, is the cause of solvent of crystallization, and probably is the fundamental reason for the swelling of high molecular weight, amorphous solids in solvents. These forces also explain many of the phenomena of adsorption, such as gases on activated carbon, the concentration of materials of high molecular weight on the surfaces of liquids, the action of so-called protective colloids on the stability of suspensions and emulsions, and the like.

CHARACTERISTICS OF CLAY SUSPENSIONS

These points of view place one in a position to explain many of the otherwise confusing characteristics of clay suspensions. The ultimate clay particles can be assumed to be excessively small flat plates. The water of chemical hydration is certainly present as hydroxyl groups, many, if not most, of which are on the external surface of the particle. The plates themselves probably consist at least in some degree of alternate layers of alumina and silica, bonded together through oxygen valence bridges. Perhaps in certain clays the outer layers are silica and in others alumina, a difference that might explain some of the differences in behavior encountered. In any event, the hydroxyl groups on the surface of the particle possess two important characteristics: first, they are highly polar, that is, around them exist strong fields of attractive force; and second, they are amphoteric, though predominantly acidic, i.e., their hydrogens are readily replaceable by metal. This is what is meant by the description of the particles as "clay acids." Thus, while clays contain predominantly silica, alumina and chemically combined water, various other metallic constituents are present. These are chiefly the alkali and alkaline earth metals, and sometimes small amounts of iron. That these constituents are not a fundamental part of the clay structure is shown by the fact that they can be removed or replaced by suitable treatment, leaving the clay particle practically unchanged. Thus, it is possible to remove the sodium and calcium by prolonging washing of the clay with strong mineral acid. Furthermore, by washing the clay with a strong salt solution, one can replace a large fraction of the calcium by sodium. This last phenomenon, known as base exchange, is apparently a mass-action effect, since the amount of metallic constituent replaced depends upon the concentration of the salt solution employed. An even clearer insight into these phenomena is obtained by producing a so-called acid clay—removing the sodium and calcium by treatment with strong acid—and then, after removing the excess of acid, titrating the suspended acid clay with alkali. The clay picks up alkali, as a weak, high molecular weight acid. In fact, the titration curve (equivalents of base added per unit weight of clay against the pH of the suspension) resembles that of a weak, dibasic acid; in this way the equivalent weight of the clay can be determined, the values ranging in the thousands.

Because of the polar character of the surface radicals, the particles attract each other; because of the flatness of their surfaces, when the particles are located close together, face to face, the total attractive force between them is considerable and their aggregation correspondingly stable. Consequently, one can build up in the suspension relatively large and long agglomerates, consisting of a series of overlapping plates. These agglomerates in any event induce in the suspension an abnormally high viscosity in relation to the volume percentage of the particles present. Furthermore, if the aggregation goes far enough, it can build up in the suspension a "brush heap" structure sufficient to convert the suspension into a gel. On the other hand, these agglomerates are not so firmly held together that they cannot be disintegrated. This can be achieved even by mechanical means; indeed, by the moderate agitation accompanying the determination of viscosity itself. This explains the general shape of the r.p.m.-torque curve; as, for example, in curves 2, 3 and 4 of Fig. 1. Violent agitation can break up the agglomerates completely, but a certain time is necessary for the disintegration. Once broken up, re-agglomeration is slow because it can occur only as the particles, agitated in Brownian movement by the impacts of the solvent molecules around them, fortuitously arrange themselves in close proximity, face to face. However, in time this will occur, thus giving an explanation of the thixotropic properties of clay suspensions.

The behavior of a clay suspension depends, however, not only on the shape and the size of the particle but also on the character of the surface and the intensity of the surface forces. Because the surface is acidic, its hydrogens can be replaced by various metals, resulting in profound transformation of the surface character. The clay acids are excessively weak, that is, the dissociation of the hydrogens is extremely small, so that the uncombined surface consists of the highly polar hydroxyl groups, closely held. Consequently, the intensity of the surface attractions is high and particle agglomerates, once formed, extremely stable. This results in a high yield point.

If, however, the clay acid is allowed to react with metal, the hydrogen of the surface is replaced by metal ion. This ion, in analogy with the behavior of the salts of all weak acids, has a far greater tendency to dissociate than the hydrogen of the acid itself. In other words, the metal ion, while held relatively closely to the face of the clay particle, is none the less much farther from the surface than the hydrogen ion that is replaced. Consequently, the surfaces of adjacent particles cannot approach as closely as before and are held together by correspondingly smaller forces. There is, therefore, less tendency for agglomerates to form and they are more readily disintegrated when formed. Hence yield point falls. Furthermore, since the volumetric changes due to these changes in surface structure must be small in comparison with the total volume of the particles, the mobility, determined as it is predominantly by the volume per cent of the suspension, is relatively little affected. Consequently, the viscosity of the suspension drops greatly. If now, instead of adding base to raise the pH and replace the hydrogens, one adds strong mineral acid, one would expect the amphoteric clay surface to react as a base, again giving a decrease in yield point for reasons analogous to those discussed above. In other words, one would expect to find a maximum yield point and, furthermore, this maximum should be on the acid side of neutrality; i.e., at a pH considerably below 7, since the amphoteric clay is undoubtedly more acidic than basic. That exactly this happens is clear from inspection of Fig. 5, which shows a marked maximum in yield point at a pH of about 5. The rise in yield point at the right of the diagram may perhaps be due to depression of ionization in the extremely concentrated alkaline solutions in question. The reasons for mobility high in strongly acid solutions and low in strong alkalis is not clear.

However, one must consider also the nature of the metallic ion, particularly its valence. With increasing valence the average distance of the metal ion from the acid surface is greatly decreased.[2] This results in increase in the intensity of the attractive forces and hence raises adhesion. This effect is beautifully illustrated by the data of Fig. 8, which shows the influence on the yield point of an acidic china clay of additions of sodium sulfate and calcium chloride respectively. The yield point is greatly depressed by the sodium sulfate, at first rapidly and then more slowly and reduced to a lesser degree by the calcium chloride. The diagram also indicates the corresponding changes in pH, though these are not sufficient to be significant. The influence of ferric chloride is shown in Fig. 7; this, unfortunately, is on another clay of low initial yield point, but it is seen that the trivalent salt produces initially a very great increase in yield point, which then goes through a maximum, but the lowest value attained is still far higher than that of the original clay. Study of the data would indicate that, while monovalent metal greatly reduces the intensity of the surface attractive forces, divalent metal also reduces it, though to a lesser degree. Trivalent metal, on the other hand, apparently increases the attraction, although it is not known what metals were initially on the surface of the particles of the clay of Fig. 7. Effects of this sort, due to the complicated phenomena of base exchange which are always occurring when a clay is brought into contact with salt solutions, are undoubtedly of extraordinary importance, but all too little is known about them. Apparently they have not been studied systematically in the light of an adequate understanding of the mechanism involved. Thus, the velocities of base exchange are often extremely low, and changes in properties otherwise unsuspected with escape notice unless this factor is kept in mind.

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[2] Consider the following analysis, which, though quantitative in form, is numerically only approximate. The metal ion capable of dissociation is undoubtedly driven away from the immediate neighborhood of the negative charge of the radical left on the surface of the clay predominantly by the impacts of surrounding water molecules. The kinetic theory indicates that the average magnitude of these impacts depends only on the temperature. The energy of impact will displace the ion a distance from the surface just sufficient to absorb the impact energy through the work done against the forces of electrostatic attraction pulling the ion back to the surface. Calling the intensity of this force f and the distance the ion moves dL, the energy expended per ion against the attractive forces should be $w = \int f dL$. If c represents the valence of the ion, a the proportionality constant of Coulomb's law, and b the charge of a single electron, substituting and integrating $w = kc\left(\frac{1}{L_0} - \frac{1}{L}\right)$, where $k = ab$ and $f = ab/L^2$, and the distance of closest approach of the metal ion to the surface is L_0. The average distance of the metal ion from the surface is unknown, but for purposes of comparison assume it to be, in the case of a monovalent metal ion, four times the distance of closest approach; *i.e.*, $L = 4L_0$. Substituting in the equation, $w/k = 3/4L_0$, whence the equation becomes $\frac{L_0}{L} = 1 - \frac{3}{4c}$. For a divalent ion, $c = 2$, $L = \frac{8L_0}{5}$, and for a trivalent ion, $c = 3$, $L = 4L_0/3$. The average displacement from the closest position expressed in terms of the closest approach is $(L - L_0)/L_0$. For a monovalent metal ion this is 3; for a divalent, 0.6; and for a trivalent, 0.33. In other words, the displacement of a divalent ion from the surface is only one-fifth that of the monovalent ion and this in turn only about one-half that of the trivalent. While the figures are certainly not quantitative, there is no reason to doubt their relative significance. Thus, these relationships are undoubtedly a predominant factor in causing the very low solubility of salts of the polyvalent-polyvalent type.

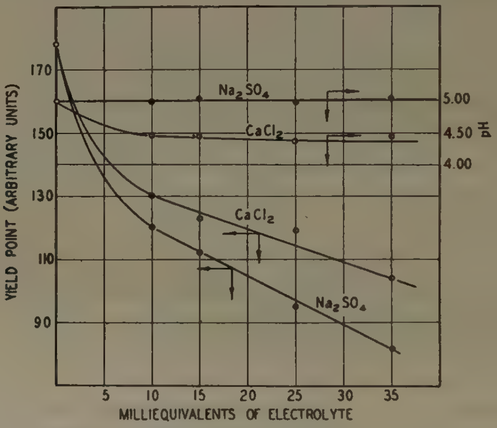

FIG. 8.—EFFECT OF ELECTROLYTES ON YIELD POINT AND pH OF A CLAY SUSPENSION.

The character of the surface of the particle can be profoundly influenced in other ways. Thus, a clay whose yield point has been brought down by adjusting the pH to a value of 11 can be still further reduced by the addition of tannic acid (see Fig. 6). The mechanism of this effect has not been demonstrated. It may be due in part to the conversion of a calcium or magnesium clay to a sodium type by preciptation of the alkaline metal as tannate. It seems probable that a more important factor is the absorption of tannic acid on the surface of a clay particle as a protective colloid. It is not improbable that the mechanism of this absorption is the combination of the tannic acid with the clay surface through a bridge of divalent metal ion. Whatever the mechanism of absorption, the protective colloid on the surface greatly reduces the effect of the attractive forces, and consequently the tendency to particle adhesion, resulting in almost complete disappearance of yield point. An entirely similar effect is shown by phosphoric acid, but the pH of maximum effectiveness of this addition agent is about 6.5, far lower than the corresponding value for tannic acid. Furthermore, with most clays the maximum result is secured only when the phosphoric acid is added at still lower pH values and the pH then adjusted by adding alkali. The mechanism is probably analogous to that in the case of tannic acid. That the tannic acid does not function primarily as a high molecular weight colloid is indicated by the high pH required to make it effective. In these strongly alkaline solutions tannic acid exists largely in the ionic state and with relatively low molecular weight; at low values of pH, where this acid exists as a colloid of high molecular weight, it is ineffective in modifying the mobility and yield-point characteristics of clay (Fig. 6).

Differences in Clays

The preceding discussion has dealt mainly with the influence of modification of conditions on the characteristics of a given clay. All too little is known of the causes of the extraordinary differences between different clays. Undoubtedly, particle size is a major factor, the finer the particle the more plastic the clay, but it seems impossible to ascribe all the differences to this single cause. The silica-alumina ration is probably a factor, the indications being that the highly siliceous clays are the more colloidal, perhaps due to a more outstanding acidic character. As already indicated, it may well be that some clays, perhaps even clays relatively high in silica, have surface layers that are predominantly alumina. This should, of course, depress the acidity of the clay and render it more inert. Particle shape may be an important factor. Thus, the fact that ground quartz shows no yield point is probably due to roughly cubical particles, which can have relatively small mutual areas of contact. Mica, with its cleavage planes, gives a considerably greater yield point (Fig. 1). Even ground silica gel, in contradistinction to ground quartz, shows a decided yield point; in view of its method of formation and its properties, one would expect it to have a large surface area, which should still persist in some degree even in the ground material.

It is not impossible that the particles of some clays are decidedly rounded, so that they touch in suspension predominantly in point rather than surface contacts, whereas others with the plate shape highly developed have the corresponding possibility of forming large, stable agglomerates. The data indicate that the finer clays gel more slowly but develop stronger structures, in keeping with the explanations here offered. The small particles are attracted by relatively weak forces which, until the particles have finally located themselves face to face, are opposed by the Brownian vibrations induced by the impacts of solute molecules. A considerable time interval is required, therefore, for the final development of agglomerate structure. Larger particles, because of the larger surface areas available, are attracted by larger forces and the interference to the associating action of these forces by Brownian vibration is a minimum. However, thoroughgoing experimental investigation of all these factors is extremely desirable.

While the characteristics of clay muds can be understood only in the light of a thorough appreciation of their behavior as colloids, a word of warning is necessary against the danger of drawing unjustifiable comparisons between the clays and many other colloidal materials. Thus, there are striking parallelisms between clay suspensions and gelatin solutions. Both are colloidal. Both exhibit Brownian movement. Both are highly viscous. Both set under proper conditions to strong and stable gels. The colloidal properties of both are profoundly influenced by the hydrogen-ion concentration (pH), showing in each case marked maxima and minima at definite pH values. The two are similarly affected by electrolytes, though in different degrees. Despite these parallelisms, the differences are fundamental. The outstanding distinction between the two types is found in the fact that in low concentrations, materials of the clay type have high and those of the gelatine type may have low mobility, relative to the fluidity of the solvent. Again, while gelatin is water soluble, it is highly resistant to most organic solvents. It is completely unaffected by hydrocarbon liquids, and is precipitated from aqueous solutions by alcohol and similar organic solvents miscible in water. The addition of small amounts of these precipitants results in a marked decrease in viscosity of the gelatin solution. Clay, on the other hand, is plasticized not only by the water but by these very organic solvents that precipitate gelatin (see Fig. 4). Indeed, using yield point as a measure of plasticization, the organic liquids are more effective than water itself. Furthermore, it is possible to reduce the yield point of a clay suspension to a negligible value (by treatment with tannic acid at suitable pH), but such treatment changes the mobility little (Fig. 3), and the viscosity of the suspension is influenced but slightly by the method of breaking the yield point by other conditions, so long as the yield point is low. Gelatin solutions also show a yield point under proper conditions and this yield point can be reduced to a negligible value; e.g., either by agitation or rise in temperature. However, here the analogy ends, because there is a large change in mobility with drop in yield point and the viscosities of solutions of zero yield point are profoundly influenced by variation in conditions; e.g., pH. Solutions of the type of gelatin in water and rubber in suitable organic solvents, when not too concentrated, show a sharp gelation temperature, below which they will set to a gel but above which they do not. Such solutions in general show no yield point at temperatures above their gel point, but at these temperatures their viscosities can be profoundly influenced by addition agents and at these temperatures if their viscosity-temperature curve is extrapolated downward it approaches an infinite value of the viscosity asymptotically at the gel point; or, what is equivalent to the same thing, the fluidity becomes zero at that temperature. In other words, the temperature of gelation can be predicted in some cases remarkably closely from viscosity behavior at higher temperatures. The changes in properties in the immediate neighborhood of the gel temperature are extraordinarily rapid. Thus, Fig. 9 shows the r.p.m.-torque curve of a gelatin solution at 30° C., and the corresponding values for the same solution agitated for different lengths of time before testing at 27° C. The gel point of this solution was 28° C. The transformation in the properties of the liquid in this narrow temperature range was extraordinary.

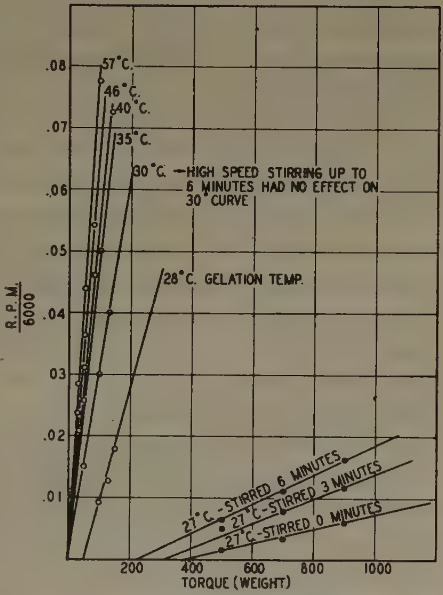

FIG. 9.—EFFECT OF TEMPERATURE AND HIGH-SPEED STIRRING ON A 20 PER CENT GELATIN SOLUTION.

These outstanding differences apparently are due to the fact that, whereas the combination of solvent with the surface of the clay particles is slight, the corresponding solvation of such amorphous colloids as gelatin and rubber is enormous. The particles of the latter combine with the solvent and swell in extraordinary degree, thereby developing high viscosity at very low concentration. Furthermore, the extent of this solvation is profoundly influenced by the temperature, increasing as temperature falls. If the solution is sufficiently concentrated, a temperature is finally reached at which the solute has combined with

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practically all the solvent. The particles themselves now fill the whole volume of the liquid and consequently tend to set to a structure; i.e., to gelatinize. In the case of amphoteric materials such as gelatin, the degree of solvation and hence the viscosity of the solution is profoundly influenced by the pH. In any case, the addition of nonsolvent miscible with the solvent desolvates the particles, breaks the viscosity and ultimately will precipitate the colloid. None of these phenomena are encountered in clay suspensions. In other words, the behavior of clay suspensions must never be confused with that of solutions of amorphous colloidal materials of high molecular weight, which solvate to high degree in solution.

Behavior of Clay Suspensions

In conclusion, it is hoped that this discussion has made it clear that extremely simple assumptions, themselves plausible in the light of all our knowledge of the structure of the clays, are adequate to serve as a thread through the complicated maze of the behavior of clay suspensions. These underlying assumptions are that the ultimate particles of the clays are extremely small, flat plates, the exterior surfaces of which consist predominantly of hydroxyl groups, chemically combined with the surface atoms of the particle structure. As is to be anticipated from the chemical characteristics of the alumina and silica of which the particles are built up, these surface hydroxyl groups are amphoteric but predominantly acidic, the acid character being extremely weak. In consequence, the highly polar hydroxyl groups exert strong fields of attractive force in the immediate neighborhood of the particle surface. Therefore, when adjacent surfaces come face to face they are firmly held together and thus are able to build up large, stable, essentially linear aggregates. This results in strong tendency to gelation. The acidic clay surface is profoundly influenced by the pH of the suspending medium. The hydrogens of the hydroxyl groups can be replaced by metals and these in turn are capable of complicated interchange. The monovalent metal salts of the clay acids are evidently highly "dissociated," thereby greatly decreasing the intensity of the surface attractions. Increasing valence of the combined metal ions progressively decreases this effect. It is possible to separate the surfaces and reduce their mutual attractions by the absorption of various materials, but these effects appear to be chemical in character rather than the simple adsorption of protective colloids of the ordinary type. The solvation of clay particles is evidently a matter of secondary importance, order of magnitude less than that of the lyophilic colloids of the type of gelatin, rubber and the like. While our knowledge of the clays is seriously limited, the data indicate that a study of their behavior from the points of view developed here offers justifiable promise of a better understanding of their characteristics and a more satisfactory classification of their properties.

Some Factors Affecting the Viscosity of Rotary Muds

By W. H. Burke*

(Tulsa Meeting, October, 1934)

Deeper drilling, resulting in greater circulating distance and pressure, has directed attention to the advantages of the study of properties and control of rotary muds, which until recently have not had much consideration. One fundamental property of muds is viscosity, and viscosity is influenced by the quantity and character of colloidal material and can be controlled by chemical treatment.

Colloidal Matter of Rotary Muds

Two types of colloids are found in muds; the hydrophobic and the hydrophilic. Hydrophobic colloids do not associate intimately with water and are sensitive to small quantities of electrolytes. Hydrophilic colloids associate intimately with water, but are not so sensitive to electrolytes. The colloidal particles of rotary muds are derived from clay. In clay the particles may range in size from submicroscopic to macroscopic; a substance is a clay if the greater proportion of the particles are within the size limits prescribed for clay. The larger particles are inert and have no effect on the viscosity of normal hydrophobic colloidal muds.

There are two theories accounting for the colloidal properties of clay-water suspensions: (1) the physical theory, that clay in water is a coarse colloidal suspension, and (2) Ashley's[1] theory, that clay is a granular material with a colloidal gel surrounding the crystalline grains. The most important colloidal substances known to exist in clays besides the clay particles are: (1) colloidal silica, (2) colloidal alumina, (3) colloidal ferric hydroxide, (4) colloidal silicates, and (5) colloidal organic matter.

Plasticity, a peculiar property of clay-water suspensions, is due to the colloidal particles. It is commonly (although not with strict accuracy) measured in terms of viscosity, and depends upon the amount and the state of flocculation of the colloidal matter present in the suspension. Fluidity in a rotary mud may be caused by a lack of colloidal clay particles or by deflocculated or flocculated clay particles, while viscosity in a rotary mud may result from an excess of clay colloids or from clay colloids flocculated to some degree. In effect, the viscosity of a mud is intimately related to the size distribution of its particles.

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* Shell Petroleum Corporation, McPherson, Kansas.

[1] H. E. Ashley: The Colloidal Matter of Clay and Its Measurement. U.S. Geol. Survey *Bull.* 388 (1909).

CORRELATION OF PARTICLE SIZES AND VISCOSITY OF ROTARY MUDS

The relationship between the particle size distribution and viscosity was determined by sedimentation and viscosity tests with several California mud materials (Wilmington Slough clay, Frazier Mountain clay, Kettleman Hills clay, and a Long Beach rotary mud. The Long Beach mud was made originally from Wilmington Slough clay).

Viscosity tests were made with a Stormer viscosimeter, which had been calibrated for motivating weights ranging from 8.8 to 517.3 grams. By varying the motivating weights it was possible to determine the viscosity of the muds at different shear rates. The percentage of particles by weight lying between the limits of 1 and 10 microns was determined from the sedimentation tests[2]. Curves derived from sedimentation tests are shown in Fig. 1. From these curves the distribution of particle size in the mud materials was computed (Fig. 2). Table 1 lists the percentage distribution of the particles.

TABLE 1.—PERCENTAGE PARTICLE SIZE DISTRIBUTION BY WEIGHT

Clay	Diameter, Microns					Total, Per Cent
	Greater than 10	Between 5 and 10	Between 2 and 5	Between 1 and 2	Less than 1	
Wilmington Slough	2.5	1.5	11	17	68	100
Frazier Mountain	9	9	25.5	25.5	31	100
Long Beach	47	6	15.5	21	10.5	100
Kettleman Hills	89.5	1	6	3.5	0	100

The relation of the colloidal content and viscosity of the mud materials can be seen by comparing the cumulative curves in Fig. 2 with the viscosity curves in Fig. 3. Further comparisons can be made by referring to Figs. 4 to 10. Those muds having the greatest percentage of small particles also have the highest viscosities. An exception is the Wilmington Slough mud, due to the hydrophilic colloidal material, probably humus, present in the mud in addition to the normal hydrophobic clay colloids. Hydrophilic colloids make the mud largely resistant to the flocculating influences that are so troublesome with the ordinary hydrophobic muds.

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[2] F. G. Tickell: The Examination of Fragmental Rocks. Stanford University Press, 1931.

CHEMICAL TREATMENT OF ROTARY MUDS TO AFFECT VISCOSITIES

Chemical treatment is generally applied to a rotary mud to increase or decrease viscosity. The methods fall into two classifications: (1) treatment with electrolytes, and (2) treatment with both colloids and electrolytes. Treatment with electrolytes is used either to increase or

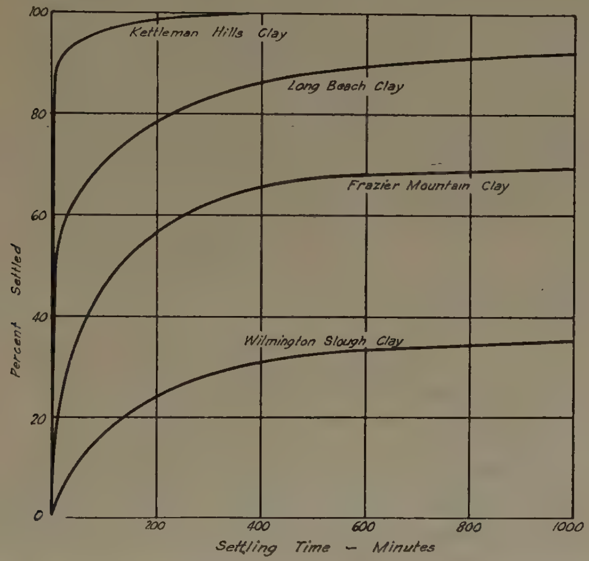

FIG. 1.—CUMULATIVE CURVES DERIVED FROM SEDIMENTATION TESTS.

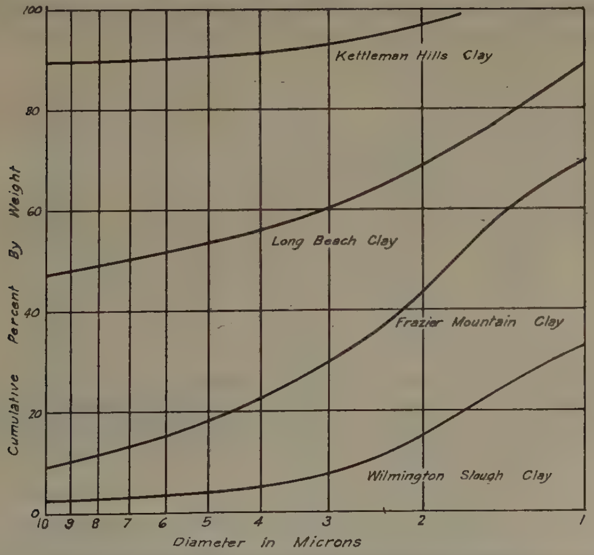

FIG. 2.—CUMULATIVE CURVES SHOWING PERCENTAGE PARTICLE-SIZE DISTRIBUTION BY WEIGHT, BASED UPON SEDIMENTATION TESTS.

decrease viscosity, while the treatment with both colloids and electrolytes usually is applied only to decrease viscosity. Usually, an untreated rotary mud will react as a negatively charged hydrophobic colloidal suspension, and the colloidal particles of the mud will be capable of both ionic and colloidal adsorption. This property makes possible the reduction or increase in viscosity. If the mud is sensitive to small quantities of electrolytes it ordinarily will exhibit flocculation and deflocculation.

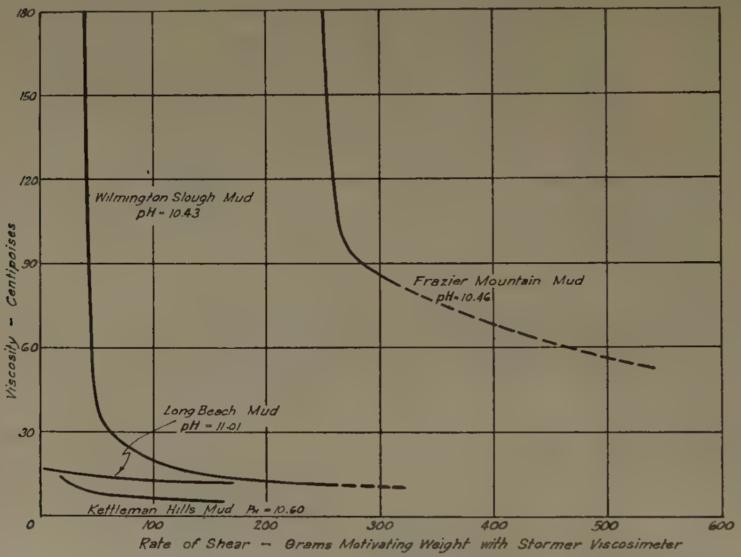

FIG. 3.—RELATIVE VISCOSITIES AT APPROXIMATELY EQUAL pH VALUES.

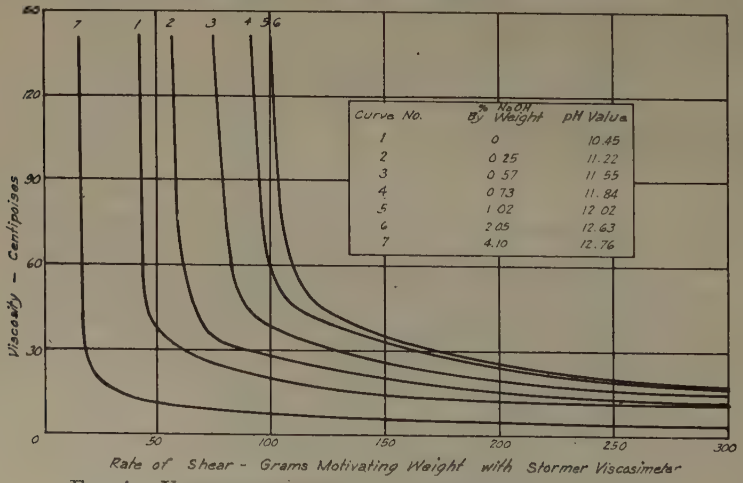

FIG. 4.—VISCOSITY CURVES FOR WILMINGTON SLOUGH MUD.

The results of treating hydrophobic rotary muds with electrolytes depend upon the effect produced on the electrical charge surrounding each colloidal particle. This electrical charge, known as the electrokinetic potential, normally depends upon the charge of the adsorbed ion. Clay colloids usually are negatively charged in an aqueous suspension and the adsorption of anions will impart an increased negative charge until the effect of the cations is felt, and then the electrokinetic potential is decreased as the concentration of the electrolyte is further increased. Thus, when the colloidal particles of a mud are subjected to such electro-

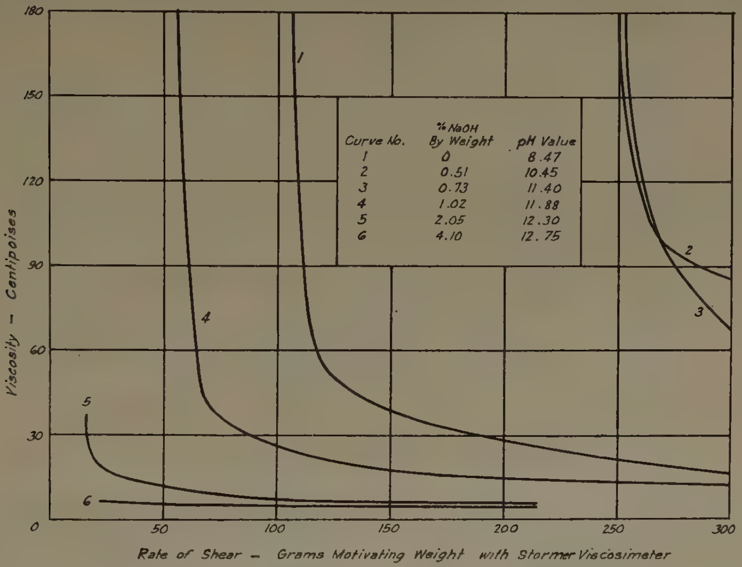

FIG. 5.—VISCOSITY CURVES FOR FRAZIER MOUNTAIN MUD.

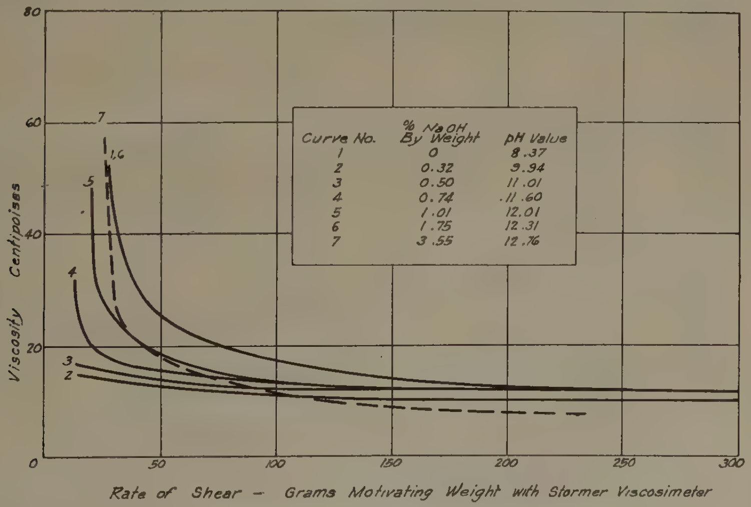

FIG. 6.—VISCOSITY CURVES FOR LONG BEACH MUD.

lytes as will raise the electrokinetic potential to a maximum value, the mud will become deflocculated or stable, and minimum viscosity will be obtained. If, however, the concentration of the electrolyte is increased so that the influence of the oppositely charged ion is felt, the influence of the adsorbed ion will decrease, the particles will flocculate, and the viscosity of the mud will increase. Further concentration of the electrolyte sometimes will cause extreme flocculation with decreased viscosity.

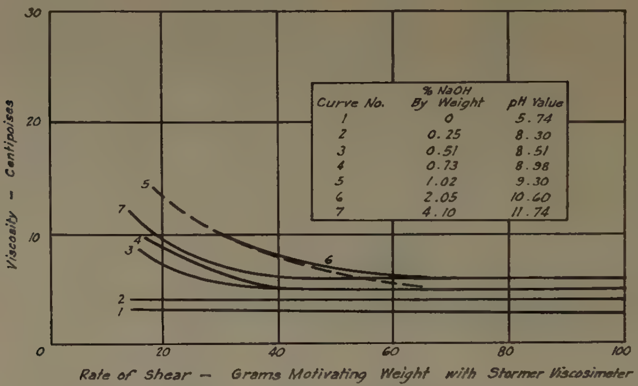

FIG. 7.—VISCOSITY CURVES FOR KETTLEMAN HILLS MUD.

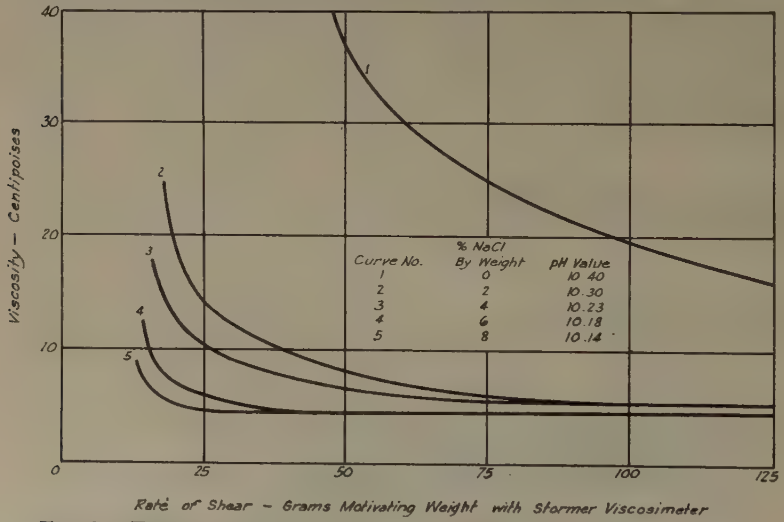

FIG. 8.—EFFECT OF SODIUM CHLORIDE ON WILMINGTON SLOUGH MUD.

These reactions can be illustrated by adding sodium hydroxide to a basic mud which is between the isoelectric point and the deflocculation point. With the addition of a small quantity of the electrolyte the hydroxyl ion will be adsorbed and the electrokinetic potential will be increased and, as the concentration of sodium hydroxide is further increased, the hydroxyl ion will increase the potential until the maximum potential is reached. Further increase in sodium hydroxide will cause a discharging effect on the potential because the influence of the sodium ion is felt. Finally, as the sodium hydroxide concentration becomes greater, the potential will become discharged. This effect of sodium hydroxide on the electrokinetic potential is reflected in the viscosity of the mud as follows: a slight increase in potential will lower the viscosity; at the maximum potential the viscosity will be a minimum; with

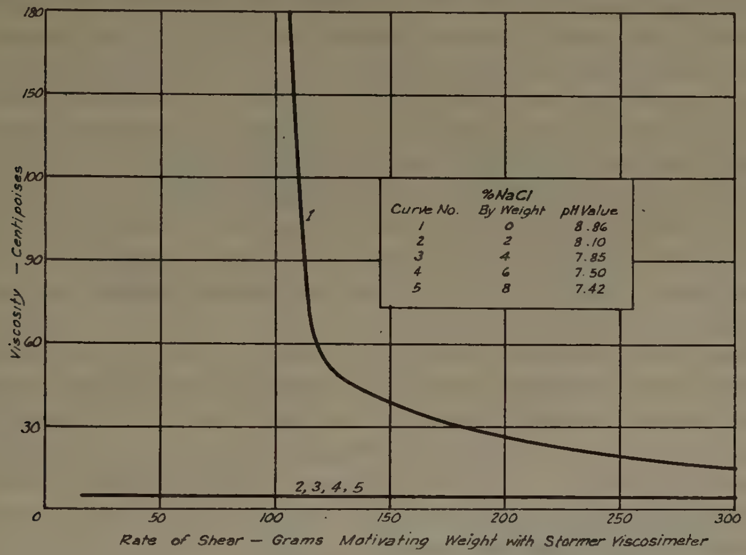

FIG. 9.—EFFECT OF SODIUM CHLORIDE ON FRAZIER MOUNTAIN MUD.

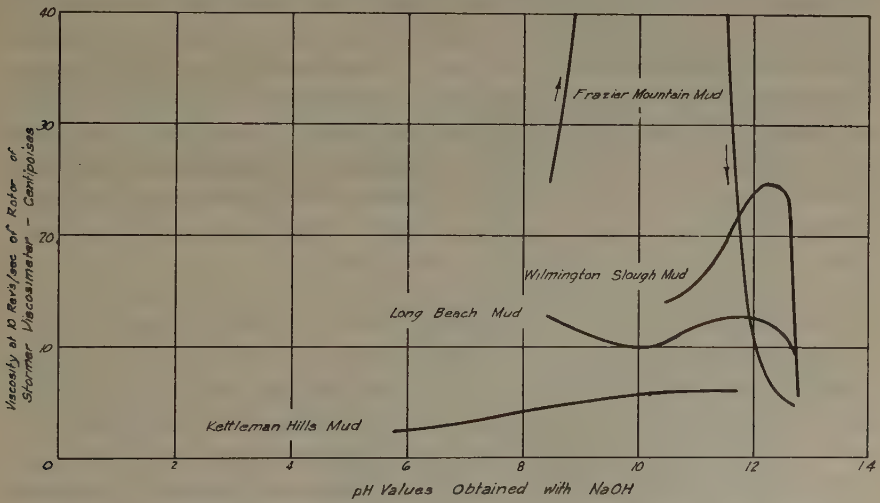

FIG. 10.—RELATIVE VISCOSITIES AT SAME SHEAR RATE VS. VARYING pH VALUES.

a decreasing potential the viscosity will increase to high values; and, finally, as the potential becomes discharged the viscosity will sometimes decrease rapidly. The decrease in viscosity with high electrolytic concentrations is caused by the complete flocculation of the colloidal particles of the mud. There is then no tendency for the particles to attract one another; in fact, they are then in masses, and because of this segregation are not able to remain suspended. The result is that the mud reacts somewhat like a fluid and large quantities of water are formed at the surface after a short period of quiescence.

Simple tests illustrating these processes were made on California muds, of which the results are shown in Figs. 4 to 8. Fig. 10 shows the results of the viscosity tests at a shear rate of 10 revolutions per second of the rotor of the Stormer viscosimeter plotted against pH values obtained with sodium hydroxide.

A mud containing positively charged colloidal particles is not desirable because of the possibility of metallic corrosion. However, it should be possible to deflocculate a rotary mud with cations. Ambrose and Loomis[3] measured the viscosities of bentonitic suspensions ranging from pH values of about 1 to 13. They did not obtain a marked minimum viscosity for an acidic suspension, although they did observe a decrease in viscosity at the isoelectric point.

The discharging effect of the cation on the maximum potential depends to a great extent upon the adsorbed anion and upon the activity of the cation. The maximum potential obtained does not depend upon the preferential adsorption of the anion. The cation makes itself felt from the start, and with the strongly active cations, such as the multivalent ones, the maximum potential becomes only a slight inflection. The hydroxyl ion, the ferrocyanide ion, the picrate ion, and the anions of many organic sulfonic acids have strong ability to establish a maximum potential[4]. A maximum potential cannot be maintained with the hydroxyl ion as with the tetravalent ferrocyanide ion, because the former is monovalent. The potential is subject to the influence of the corresponding cation with the hydroxyl ion, while the corresponding cation of the ferrocyanide ion has little effect.

A partial index to the state of flocculation of a mud is its pH value, but as this value has no meaning if an electrolyte of a neutral salt, such as sodium chloride, is present in the suspension, it is important to state the electrolyte in the suspension when reporting the pH value of a mud. For example, the same state of flocculation may be obtained at a lower pH value with sodium carbonate than with sodium hydroxide because of the differences in the dissociation constants of the two bases. Generally, however, the pH value of a mud is an indication of its degree of flocculation. Figs. 8 and 9 show that the viscosities of Wilmington Slough and Frazier Mountain muds were reduced by the addition of sodium chloride. The pH values were not greatly affected.

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[3] H. A. Ambrose and A. F. Loomis: Some Colloidal Properties of Bentonite Suspensions. *Physics* (1931) **1**, No. 2.

[4] H. A. Freundlich: Colloid and Capillary Chemistry, 258. New York, 1922. E. P. Dutton and Co.

Treatment with colloids is perhaps the most interesting phase of the chemical treatment of rotary muds. The process appears to consist in changing the colloids of the mud from hydrophobic to hydrophilic, thus reducing the effect of the contaminating electrolytes. It is probable that the added hydrophilic colloids surround or protect the more sensitive clay colloids.

The hydrophilic colloids have two conditions of stability in contrast with one for the hydrophobic colloids. Both classes have a stability condition dependent upon the electrical charge carried by the particles. The hydrophilic colloids, in addition, have a stability condition due to the solvated condition of the particles. Thus, because of the apparent readiness of the surrounding or protecting action, and because of the two conditions of stability of the hydrophilic colloids, it is usually possible to control the viscosity of the mud by adding the hydrophilic colloids. The ability of these hydrophilic colloids to decrease in viscosity with increase in concentration of electrolytes and yet remain stable makes them valuable in mud work. In general, as the concentration of certain electrolytes increases, the viscosity of hydrophilic colloidal suspensions decreases, and the suspensions will remain stable up to salting-out points.

Tannin is the most commonly used of the hydrophilic colloids in mud work. Quebracho crystals are a very good source, the tannin content being about 80 per cent. Lawton, Ambrose, and Loomis[5] found peat, chestnut extract, sulfite waste liquor, sap brown, spent liquor, tannic acid or humic acid, when mixed with caustic soda, effective in reducing the viscosity of Pierce Junction rotary mud. They found tannic acid or humic acid alone not so effective as when used with caustic soda.

SUMMARY

The viscosity of a rotary mud depends upon the amount of the colloidal content and the character and state of flocculation of the colloidal matter. Viscosity may be due to an excess of clay colloids or to clay colloids flocculated to some degree. Fluidity of a mud may be caused by absence of clay colloids, by flocculated or deflocculated clay colloids, or by the presence of proper hydrophilic colloidal matter.

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[5] H. C. Lawton, H. A. Ambrose and A. G. Loomis: Chemical Treatment of Rotary Drilling Fluids. *Physics* (1932) **2**, No. 5.

Effects of Temperature, Pressure and Water-cement Ratio on the Setting Time and Strength of Cement

By B. C. Craft,* Member A.I.M.E., T. J. Johnson† and H. L. Kirkpatrick†

(Tulsa Meeting, October, 1934)

Petroleum engineers are displaying considerable interest in the problems of cementing oil wells, especially in the Gulf Coast and California areas, where steep temperature gradients are encountered and where wells are being drilled to greater depths. Deep drilling, that is, at depths in excess of 7000 ft., has been undertaken in these areas only in the last few years and with this trend oil-well cementing requires more technical treatment.

It is not the purpose of this paper to describe the scope and application of cement operations in the oil industry or to give the standard specifications, methods of sampling and testing of portland cement. The various testing methods have been described by the American Society for Testing Materials[1], Uren[2], Tickell and Wankowski[3] and Rakestraw and Parsons[4]. The latter authors (pp. 50–58) have also described in detail the methods of cementing.

The authors realize that it is impossible to reproduce in the laboratory the scale of forces and dimensions that exist at great depths, but an attempt has been made to scale down these dimensions proportionally. The selection of problems to be studied was based largely upon the practical questions asked by several of the largest operators in these fields. All cements used in these experiments met the specifications of the American Society for Testing Materials.

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* Assistant Professor of Petroleum Engineering, Louisiana State University, Baton Rouge, La.

† Louisiana State University, cooperative project with the Graduate School.

[1] Standard Specifications for Natural Cements. A.S.T.M. Designations: C 10-09, C 9-30, C 77-32. Amer. Soc. Test. Mat. (1933).

[2] L. C. Uren: Various Methods of Testing Portland Cement for Oil Field Purposes. *Oil Field Eng.* (1927) **2**, No. 5, 31–36.

[3] F. G. Tickell and V. O. Wankowski: Oil Well Cements—The Effects of Pressure on Their Physical and Mechanical Properties. *Oil Field Eng.* (1928) **4**, No. 3, 16.

[4] T. H. Rakestraw and C. P. Parsons: Current Oil Well Cementing Practice. Petr. Eng. Handbook, 2d ed., 48. Los Angeles, 1931. Palmer Publications, Inc.

SERIES I.—EFFECT OF WATER-CEMENT RATIO ON SETTING OF CEMENT IN LONG COLUMNS

The laboratory apparatus for this experiment consisted of 16 ft. of 1-in. glass tubing mounted on a plank. Various mixes of neat cement slurry varying from 40 to 60 per cent water by weight were poured into the tubing and allowed to approach initial set. A slurry having 50 per cent of water by weight or having a density of 112.99 lb. per cu. ft. formed a solid cement plug. This was also true of all mixes of less than 50 per cent or weighing more than 15.09 lb. per gallon. Mixes weighing less than 15.09 lb. per gallon separated into cylinders of neat cement from 6 in. to 4 ft. long, separated by horizontal breaks of clear water from ¼ to ½ in. high. The results obtained in the lower part of the tube with a 55 per cent mix are given in Table 1. The horizontal breaks in the cement developed about 15 minutes after the cement was placed in the glass tubing. During the formation of the breaks, movement of water was observed along the side of the tube up into the clear water areas.

TABLE 1.—*Horizontal Breaks in Cement Column Using* 55 *Per Cent Mix*[a]

Distance from Bottom of Glass Tubing to Water Layer		Thickness of Water Layer, In.	Distance from Bottom of Glass Tubing to Water Layer		Thickness of Water Layer, In.
Ft.	In.		Ft.	In.	
	8⅜	⅛	8	2⅛	⅛
4	4	⅜	9	4⅞	¼
5	6½	¼	10	3½	⅛
6	6	⅛	11	4¼	⅛
7	4⅝	¼			

[a] Sample placed in glass tubing at 2.25 p.m.; measurements taken at 3 p.m.

This action may be explained by the fact that thin solutions of water and cement behave as colloidal solutions, the heavier cement particles having a tendency to settle out before hydration of the cement takes place. The heavier and more viscous mixes do not show this tendency because of the greater concentration of solids. It is believed that pressure plays a very small part in this behavior, as separations took place at rather regular intervals from the bottom to the top of the tube. Failures in plugging off bottom water and plugging back to shallow sands may be due to the use of too light a mix in these operations.

SERIES II.—EFFECT OF TEMPERATURE AND WATER-CEMENT RATIO ON TIME OF INITIAL SET AND COMPRESSIVE STRENGTH

That the setting time of portland cement is greatly influenced by both temperature and water-cement ratio has been shown by Uren, Rakestraw and Parsons, Backman and others. The work of these experimenters[5,6,7] is particularly interesting because they illustrate the general effects due to change of the variables.

In order to compare the setting time and compressive strength of neat portland cement with high-early-strength cement and with water-cement ratios satisfactory for general oil well work, a series of experiments was conducted. The apparatus consisted of a small bath equipped with a 250-watt heating element, thermostatic temperature control, an electric stirrer and thermometer. With this equipment it was possible to keep the water in the bath at a constant temperature for any desired length of time. The cement was mixed with water at 70° F., agitated for three minutes with an electric stirrer and poured into standard 2 by 4-in. split molds, which in turn were submerged so that the surface of the cement was covered by the bath water. It was necessary to seal a glass cover plate to the bottom of the molds to prevent leakage. The neat cement was allowed to harden to the point of initial and final set, these determinations being made by a standard Vicat needle. The molds were then removed from the bath and placed in an oven at the same temperature as that of the bath and allowed to remain for 72 hr. The molds were then removed from the oven, the cement cylinders were

TABLE 2.—*Effect of Temperature and Water-cement Ratio on Time of Initial Set and Compressive Strength with Portland and High-early-strength Cement*

Temperature, Deg. F.	High-early-strength Cement					Neat Portland Cement					
	Time for Initial Set, Min.			Compressive Strength at 72 Hr., Lb. per Sq. In.		Time for Initial Set, Min.			Compressive Strength at 72 Hr., Lb. per Sq. In.		
	40% Mix	50% Mix	60% Mix	50% Mix	60% Mix	40% Mix	50% Mix	60% Mix	40% Mix	50% Mix	60% Mix
130	89	104	125	3230	2150	130	133	160	3160	2205	1368
140	77	96	114	3270	2160	121	138	152	3040	2060	1225
150	60	69	82	2520	1582	106	118	137	3350	1960	1285
160	55	64	77	2520	1541	93	114	126	4100	2250	1335
170	50	57	68	2603	1810	88	100	119	2645	2000	1025
180	38	48	54	2320	1598	84	94	105	2300	2010	900
190	28	34	37	1650	1248	66	70	87	2280	1430	700
200	18	25	26	1365	810	54	57	75	1550	1150	690
205	17	24	25	1550	875	49	56	74	1440	970	335

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[5] L. C. Uren: Petroleum Production Engineering-Development, 2d Ed., 374, New York, 1934. McGraw-Hill Book Co.

[6] T. H. Rakestraw and C. P. Parsons: Reference of footnote 4, 48–50.

[7] L. F. Backman: Service Data for Oil Well Development. A report circulated by the Pacific Portland Cement Co. (1926). Cited by Tickell and Wankowski: Reference of footnote 3, 18.

extracted, and the compressive strength was determined. It was believed that curing the cement in an oven duplicated as closely as possible typical field conditions, because the walls of a well are thoroughly mudded before the introduction of cement, which would make them quite impermeable to water. Samples cured in water at 180° F. showed a relatively lower compressive strength than those cured in the oven at the same temperature.

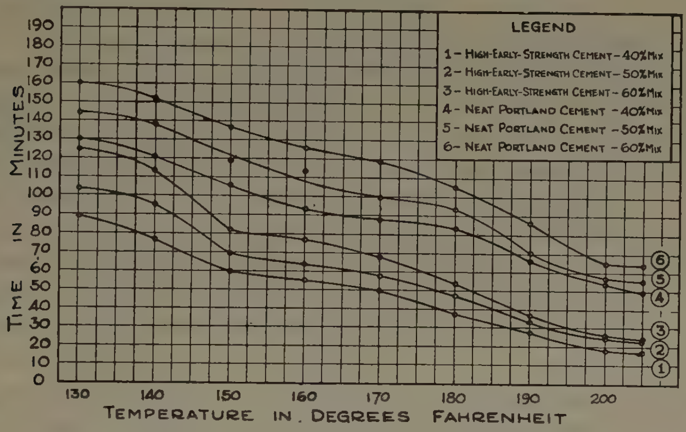

FIG. 1.—EFFECT OF TEMPERATURE ON TIME OF INITIAL SET.

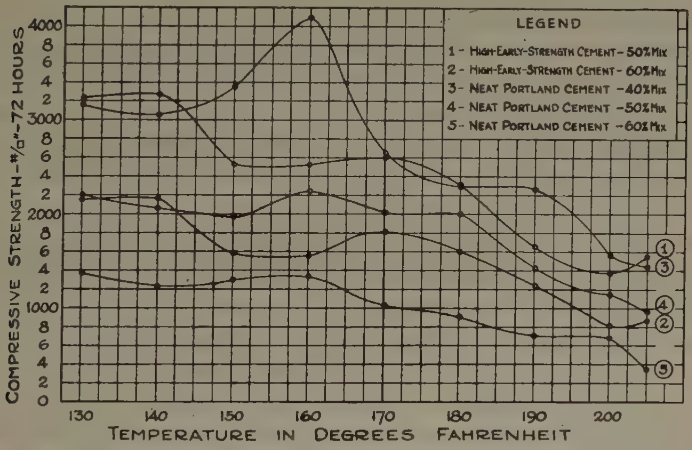

FIG. 2.—EFFECT OF TEMPERATURE ON COMPRESSIVE STRENGTH.

The results of these tests are shown in Table 2 and Figs. 1 and 2. The curves for the effects of temperature on the time of initial set show reasonable conformity, except for the high-early-strength cement in the region of 190° to 205° F., where the time for initial set is approximately the same regardless of increase in temperature. A possible explanation of this behavior is that the rate of hydration can be increased only to a limited extent, regardless of the temperature or percentage mixture.

Cements set at high temperatures develop a flash set, which would indicate that the cement should be kept in motion, especially when the time required for placing the cement is longer than that required for initial set. The slurry maintains nearly a normal consistency within five minutes of initial set. Expansion was especially noticeable with temperatures above 160° F., the action taking place just before the time of initial set. The results obtained from one brand of portland cement are given for illustration; however, tests on another brand gave substantially the same results. The obvious conclusion from these experiments was that both temperature and water-cement ratio affect the setting time. The curves for the effect of temperature on compressive strength (Fig. 2) show that the compressive strength decreases materially with a rise in temperature and is also affected by the water-cement ratio. The writers are unable to give a reason for the increased strength in the region of 160° F. obtained with the neat portland cement, except that possibly the hydration is more complete at this temperature. The curves for both types of cement are nearly conformable, indicating that the same reactions take place regardless of the water-cement ratio.

SERIES III.—EFFECT OF TEMPERATURE AND PRESSURE ON TIME OF INITIAL SET AND STRENGTH OF NEAT PORTLAND CEMENT

It was considered necessary to determine the effect of temperature and pressure on the time of initial set and compressive strength of portland cement, as it was thought that these data would more nearly approach actual field conditions. The equipment consisted of a standard Vicat apparatus welded to the inside of the autoclave, and so placed that when the Vicat needle was in a raised position it was in contact with the cement. Connections were made so that the Vicat slide could be raised manually by means of a cam on an arm leading through a stuffing box to the outside. The cam made contact with a pin in the slide, which translated motion to the needle, so that it could be raised exactly 3.5 cm. and could fall the same distance. When the cam made contact with the pin above 3.5 cm., as indicated by graduations on the cam control, the cement had passed initial set. The cement sample was poured into a standard 2 by 4-in. split mold, which was placed on a footplate and rotated by means of a rod that passed through a stuffing box in the bottom plug, so that the needle would penetrate a fresh surface of cement on each trial. A 4-in. hydraulic plug was cut and threaded to fit the inside of the autoclave at the bottom, and machined with a male on each side of which were grooves to receive lead gaskets. A female was machined in the bottom of the autoclave to receive the male on the plug. The male was seated on a lead gasket fitted in the female, thus forming a triple seal. The thermometer well was placed ½ in. above the cement molds. Temperature was controlled by a 500-watt heating element placed inside and at the bottom of the autoclave. Later this was replaced by four 550-watt heating elements made of nichrome wire wrapped around the outside of the autoclave. Water was added and pressure applied by means of a duplex hand hydraulic pump using the 1¼-in. piston for pressures up to 1000 lb. and the ⅝-in. piston for pressures up to 6000 pounds.

The procedure followed in making a test was as follows: The water in the pump reservoir was heated to about 20° above the desired temperature for the test. With the plug in, the autoclave was filled with water and brought to a temperature slightly above that desired. Mixing water at 70° F. was then added to the cement and agitated for 3 min. Then the plug was removed and the cement mold, covered with a paper towel to prevent splashing, was placed on the footplate and the plug was screwed into place. The autoclave was again filled with hot water and the desired pressure applied.

The results of some of the tests are shown in Table 3, from which the conclusion must be drawn that there is an average decrease in time of initial set of 10 min., with temperatures between 130° and 200° F. and pressures between 500 and 2500 lb. That pressures above 500 lb. have little effect is shown by the sets obtained at 200° F. with pressures of 500 and 2500 lb. These results compare favorably with those of Tickell and Wankowski[8], who found that a pressure of 1500 lb. caused a reduction in initial setting time of 30 min. in 7 hours.

Cement set under pressure for 72 hr. at 180° F. and 2000 lb. pressure showed an increase in compressive strength over that set at atmospheric conditions of 1660 lb. per sq. in., while that set at 205° F. showed the remarkable increase of 3375 lb. per sq. in. Cement set at 250° F. and 2000 lb. showed practically the same compressive strength as that at 205° F. These results substantiate the early work of Bell and Grimm[9], who found that there was an appreciable increase in tensile strength when samples were cured in a well at 1650 ft. and compared with those set under atmospheric conditions, and compare favorably with the tests made by Doherty[10]. Cements set at 300° and 325° F. under 2000 lb. pressure, while having a low compressive strength, were not porous, which was characteristic of cements set at 205° F. under atmospheric pressure, indicating that satisfactory cementing operations may be carried on under these conditions. Temperatures of 256° F.[11] have been recorded in California fields and reported elsewhere. From laboratory data it would be concluded that satisfactory cement may be obtained at these temperatures and pressures.

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[8] F. G. Tickell and V. O. Wankowski: Reference of footnote 3, 18.

[9] H. W. Bell and M. W. Grimm: Some Tests on Cement and Cement Accelerators. *Bull.* Amer. Assn. Petr. Geol. (1928) **12**, 279–281.

[10] W. T. Doherty: Oil-Well Cementing in the Gulf Coast Area. Amer. Petr. Inst. Production *Bull.* 212, 5.

[11] McCaslin Perennial Starts Flowing After "Shot." *Petr. World* (Feb., 1934) 22.

TABLE 3.—*Effect of Temperature and Pressure on Time of Initial Set and Compressive Strength with a 50 Per Cent Slurry of Portland Cement*

Temperature, Deg. F.	Atmospheric Results		Hydraulic Results		
	Time for Initial Set[a], Min.	Compressive Strength at 72 Hr., Lb. per Sq. In.	Autoclave Pressure, Lb. per Sq. In. Gage	Time for Initial Set, Min.	Compressive Strength at 72 Hr., Lb. per Sq. In.
130	98		500	87	
140	93		1000	82	
150	79		1500	69	
160	72		1500	63	
170	68		2000	60	
180	63	2240	2000	54	3950
180	63		4000	53	3900
190	60		2000	52	
200	56		2500	45	
200	56		500	44	
205	56	405	2000	43	3780
205	56		2500	42	
220	[b]		2500	29	
230			2500	28	
230			2500	27[c]	
240			2500	28	
250			2000	29	3815
275			2000		2680
300			2000		765
325			2000		760

[a] Different sample used from that for which tests are given in Table 2.

[b] Cement boiled out of the mold above 205° F. [c] Forty per cent slurry.

ACKNOWLEDGMENTS

The writers gratefully acknowledge their indebtedness to Prof. F. G. Tickell, Professor of Petroleum Engineering, Stanford University, for his helpful assistance in designing the autoclave; to Mr. H. L. Lehmann and Mr. A. E. Lowman, of the Louisiana Highway Commission, who assisted in the observations; to Mr. H. L. Laws, of the Cinclare Central Factory, for the use of equipment; to Mr. S. Barna, of the Standard Oil Company of Louisiana; and to Dean C. W. Pipkin, of the Graduate School, Louisiana State University.

New Type of Dynamometer for Study of Pumping Problems

By Emory Kemler*

(New York Meeting, February, 1935)

The problem of determining the most desirable operating conditions of an oil-well pumping unit or rig front, the selection of the proper material and size of sucker rods, and the design of a pumping unit require that sucker-rod loads be known with a reasonable degree of accuracy. The segregation of rig losses, the proper selection and operation of prime mover and reduction unit, and the analysis of the operation of subsurface equipment require a knowledge of polished-rod horsepower. The investigation of such problems as the instantaneous stresses set up in a pull-rod line or backside crank installation when the well is suddenly hooked on, a study of such problems as the effect of anchoring the tubing on rod load, tubing stresses and rod horsepower, and an analysis of the effect of subsurface equipment on rod loads make it necessary to have a dynamometer that is rugged, which can follow the sudden changes in load without any lag or damping effect, which will record the load in its true position with respect to polished-rod movement, and which will give a card large enough to allow the desired effects to be measured accurately.

The inadequacy of the spring or fluid-pressure type of dynamometers has been covered in detail[1]. The data given show that dynamometers of the spring or fluid-pressure type exert a damping action on the peak loads and the inertia and friction of their load-indicating mechanism introduces a phase lag in recording the load. A dynamometer of that type will not give the load in the correct amount and will not record it in its true position with respect to stroke or time.

NEW TYPE OF DYNAMOMETER

Fig. 1 shows a magnetic strain-gage type of dynamometer, to be described in this paper. The strain gage *A* is used for measuring the load in the polished rod, a washer *B* and knife edge *C* take care of initial misalignment and reduce bending in the compression tube of the strain gage. The complete instrument can be transported in the carrying case *E*.

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* Engineering Division, Gulf Research & Development Corporation; Assistant Professor of Mechanical Engineering, University of Pittsburgh.

[1] B. B. Wescott, E. N. Kemler and H. D. Collins: Dynamometers for the Study of Pumping Problems. *Petr. Engr.* (May, 1934) 30 to 36.

Fig. 2 shows three types of strain gages applied to a well. The gage is applied by attaching polished-rod clamp *G* just above the stuffing box. The walking beam is then lowered and the load removed from the polished rod. Clamp *H* is removed and the gages are slipped over the polished rod. Clamp *H* is then replaced above the gages, the load picked up, and clamp *G* removed. A string or wire attached to the hanger or walking beam is then connected to the stroke-recording mechanism in the recorder *D*. The dynamometer is now ready to record the load.

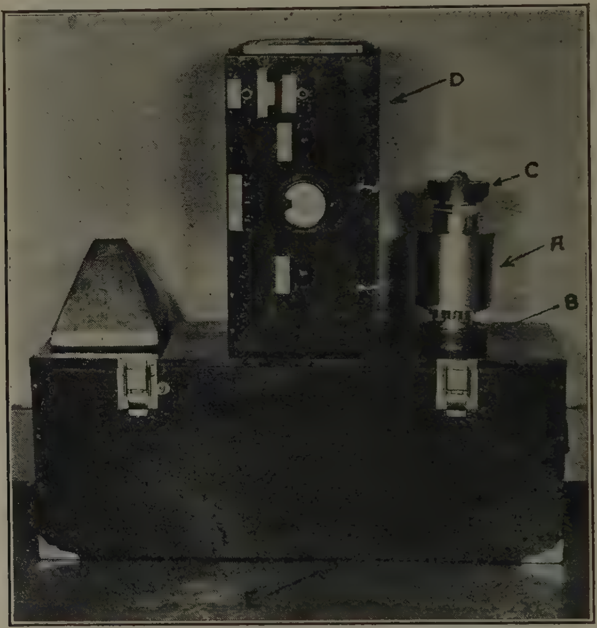

Fig. 1.—Magnetic strain-gage dynamometer.

A. Strain gage.	*D*. Recorder.
B. Washer.	*E*. Carrying case.
C. Knife edge.	

Fig. 3 is a schematic drawing of the recorder. The recorder consists essentially of an oscillograph (1) and a reducing motion (3). The oscillograph records in a vertical direction the load as measured by the strain gage, and the stroke is recorded in a horizontal direction through the reducing mechanism. The load and stroke are recorded on screen 7 by a spot of light, which originates from lamp 20. The light from the lamp passes out through a small hole 23 in cover 22. The light beam passes through lens 80, is reflected from a small mirror in the galvanometer and travels back to the screen. As the polished rod moves up and down, the oscillograph oscillates in a horizontal direction, causing the spot of light on screen 7 to move back and forth horizontally. Variations in the load as the polished rod moves up and down cause an unbalanced

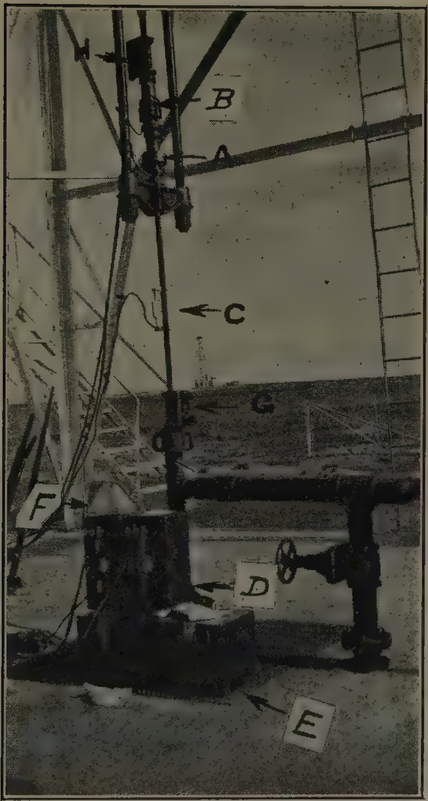

FIG. 2.—THREE GAGES APPLIED TO A WELL.

A. Experimental magnetic gage.
B. Carbon pile gage.
C. Telemeter.
D. Recorder.
E. Carrying case.
F. Viewing hood.
G, and *H*. Clamps.

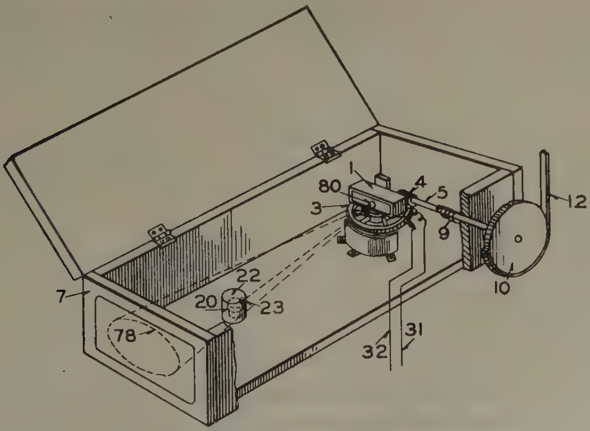

FIG. 3.—SCHEMATIC DRAWING OF RECORDER.

current proportional to the load to flow through the oscillograph. This causes the oscillograph mirror to tilt about a horizontal axis, and causes the light beam to move up and down as the load varies. The resulting curve will be a load-displacement diagram, which can be viewed on the screen or can be photographed for permanent record.

Fig. 4 shows a schematic drawing of the magnetic strain gage. The essential parts of the gage are the compression tube, the armature and the pole pieces, each of which carries a coil. The gage is assembled so that there is an air gap between the pole pieces and the armature. The measuring circuit, shown in principle in Fig. 4, is a wheatstone bridge consisting of two variable impedances made up of the coils mounted on the pole pieces and two fixed resistances R_1 and R_2. When there is no load on the gage the resistances R_1 and R_2 are adjusted so that either no current or a fixed amount of current passes from A to B. When current passes from A to B it passes through the rectifier, thence through the choke coil and the oscillograph. The oscillograph then records or indicates the amount of unbalanced current. When a load comes on the gage the armature is caused to move in relation to the pole pieces and thereby causes a change in the air gap on each side. The change in air gap causes a change in the impedance of the coils, which results in an unbalance of the circuit, which is made proportional to the load.

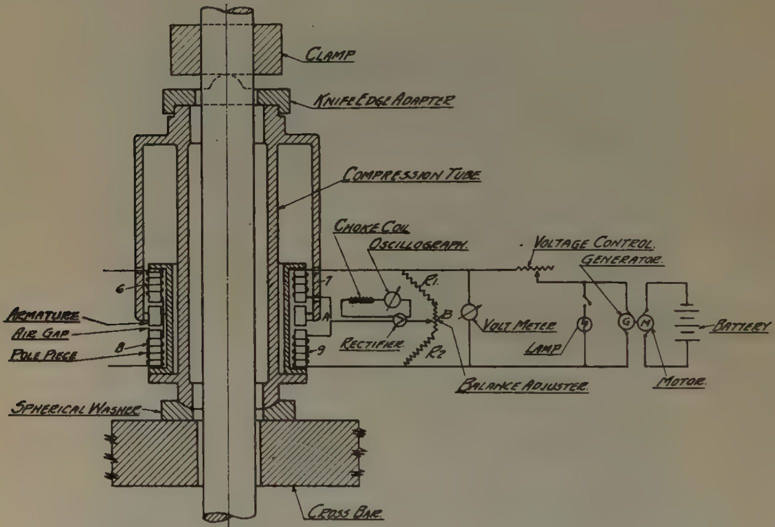

FIG. 4.—SCHEMATIC DRAWING OF MAGNETIC STRAIN GAGE.

Two sets of coils, 6–8 and 7–9 are used to measure the load. These are mounted diametrically opposite on the compression tube and are adjusted so that if any bending occurs in the tube it will not influence the load recorded; any such bending results in one set of coils giving a higher reading and the other set a lower reading, the sum being only the direct load.

In order to reduce the amount of current drawn by the coils it is necessary to use high-frequency alternating current as the power supply. For this purpose a small motor-generator set, operating from a 6-volt storage battery and generating 6-volt, 500-cycle alternating current is used. The entire dynamometer, consisting of the battery, motor-generator set, recorder, gage, viewer, film packs, cable, and other miscellaneous parts can be placed in the carrying case, which is 11 by 10⅝ by 30 in. and weighs approximately 85 pounds.

RECORDS MADE BY DYNAMOMETER

Figs. 5 to 10 inclusive show cards taken with this dynamometer. Fig. 5*a* shows a card taken on a long-stroke pumping unit making eight 11-ft. strokes per minute. The well had 2200 ft. of ⅞ in. rods and was equipped with a 4-in. pump. Fig. 5*b* is a card from the same well with all conditions the same except that the rig was reversed. The peak load in 5*b* is 14,700 lb., as compared with 14,200 in 5*a*. The polished-rod horsepower is practically the same, being 25.1 as compared with 24.8, the difference being less than the errors that might arise in measuring the area of the cards.

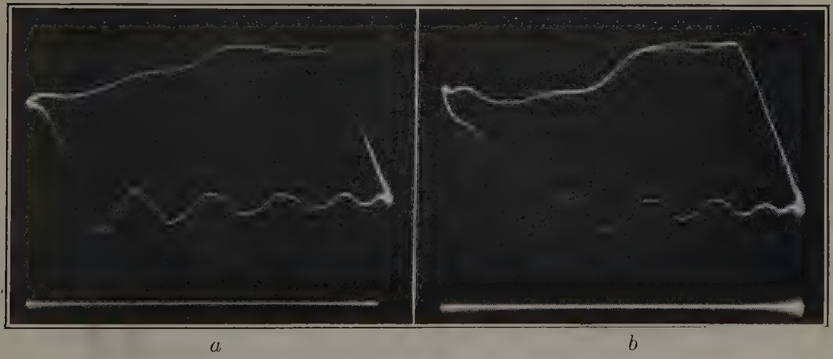

FIG. 5.—CARDS TAKEN ON LONG-STROKE PUMPING UNIT.
a. Rig in usual arrangement.
b. Rig reversed.

Fig. 6 shows a card taken from a 3100-ft. well making eighteen 62-in. strokes per minute. This card shows two traces, one taken immediately after the other, indicating the differences that may be found from one stroke to the next.

Fig. 7 shows a card taken on a rig equipped with an elliptical gear crank. The sudden changes in load at the end of the downstroke are caused by a broken gear tooth, which let the load drop off for an instant just at the end of the downstroke.

Fig. 8 shows a card for a well that was pounding fluid. The load is very nearly constant on the downstroke until the plunger hits the fluid in the pump; then there is a sudden drop of load.

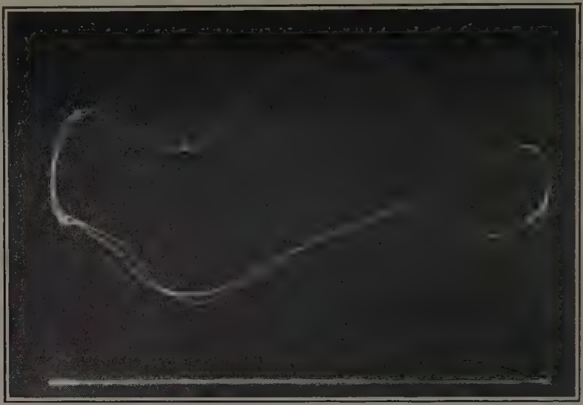

FIG. 6.—CARD SHOWING TWO TRACES, WHICH INDICATES DIFFERENCES BETWEEN STROKES.

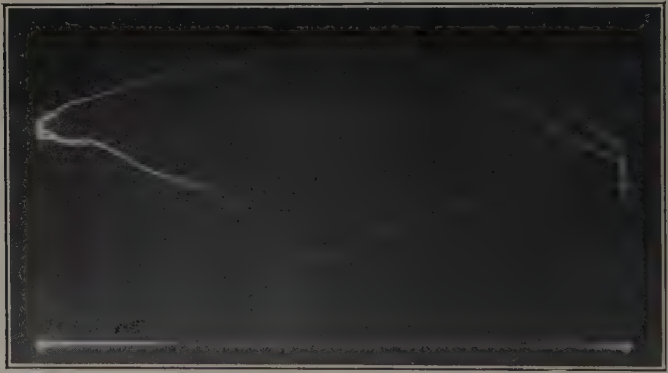

FIG. 7.—CARD TAKEN ON RIG EQUIPPED WITH ELLIPTICAL GEAR-TYPE CRANK.

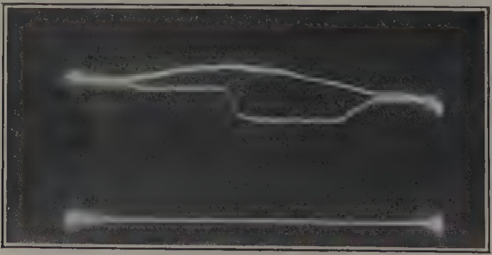

FIG. 8.—CARD TAKEN ON WELL THAT WAS POUNDING FLUID.

Figs. 9*a* and 9*b* are taken on the same well under as nearly the same well conditions as possible. The fluid level was nearly the same and the well made very little gas. Fig. 9*a* was taken with the pump making twenty-three 72-in. strokes per minute and Fig. 9*b* was with thirty-four 50¼-in. strokes per minute, which gives equal polished-rod travel. Fig. 9*b* shows the type of card that is obtained when the pumping speed is so fast that the polished-rod clamp leaves the hanger. The sudden increase of load near the middle of the downstroke is caused by the polished-rod clamp hitting the hanger crossbar when it catches up with it. This card shows the sensitivity and the speed with which the dynamometer can follow the load. The speed at which the load increased was so great that the light exposure was not long enough to leave a normal trace.

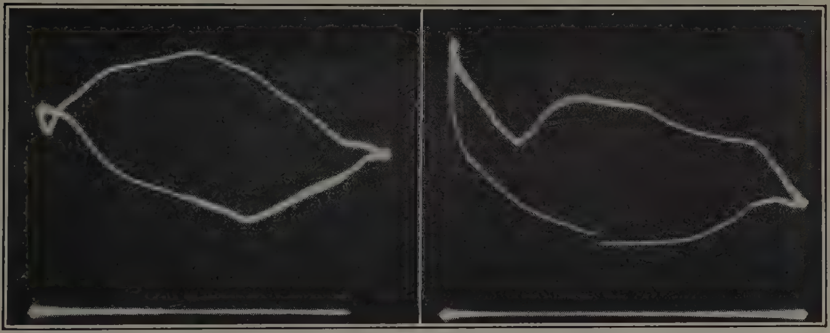

Fig. 9.—Cards taken on same well in conditions as nearly alike as possible.
a. Pump making twenty-three 72-in. strokes per minute.
b. Pump making thirty-four 50¼-in. strokes per minute.

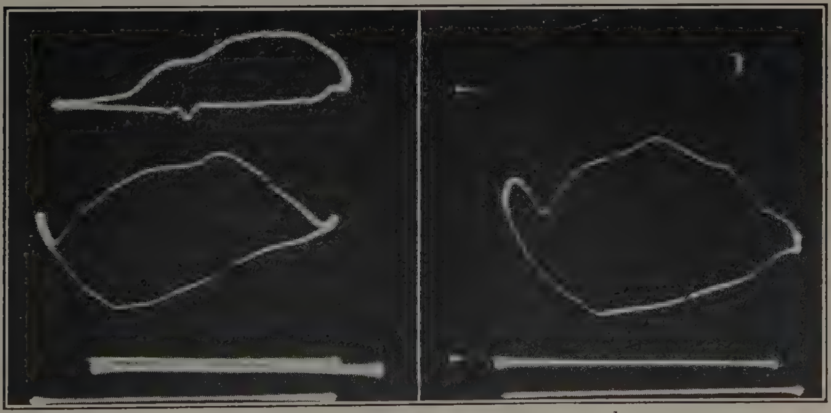

Fig. 10.—Cards on which tubing and rod loads were taken simultaneously.
a. Pump making twenty 50-in. strokes per minute.
b. Pump making twenty-five 50-in. strokes per minute.

Figs. 10*a* and 10*b* show cards on which tubing loads were recorded as well as rod loads. The rod loads were taken on a magnetic dynamometer and the tubing load taken on a carbon-pile dynamometer. The two dynamometers, unfortunately, were hooked up so that they recorded in opposite directions, and the start of the upstroke therefore starts on opposite ends of the card. Fig. 10*a* was taken at twenty 50-in. strokes per minute and 10*b* at twenty-five 50-in. strokes per minute. The sudden decrease of load on the tubing card during the upstroke was accompanied by a decided banging noise and apparently was caused by a rod joint catching on a tubing joint.

Interpretation of Dynamometer Cards

The use of dynamometer cards in the study of the operation of subsurface equipment requires a study of the form of card as well as a determination of the loads and horsepower. The cards included with this paper were chosen to illustrate the effects of the different operating conditions on the form of the card, as well as to show the kind of card obtained with this new dynamometer. As our knowledge of the effects of subsurface operating conditions on the form of dynamometer cards becomes better understood, the dynamometer will become more useful and necessary in the study of pumping problems and in the establishment of the best operating conditions. For such work, therefore, it is necessary to have a dynamometer that will record the load in correct amount and its true position with respect to polished-rod movement.

One commonly accepted statement is that the peak rod load depends on the maximum rod acceleration. Under normal operating conditions, other factors exert a greater influence on the shape of the card and on the peak load than maximum rod acceleration. Such a condition should be expected from study of the forms of dynamometer cards.

The maximum upward acceleration of the polished rod occurs at the start of the upstroke of the pump, and if this were the controlling factor we should expect the peak load to occur at this point. As a matter of fact, typical cards such as those shown in Figs. 6, 7, 8, 9*a* and 10 show that the peak load occurs near, or even after, the middle of the upstroke, at which point the rod acceleration will be zero or negative.

The primary factors in the total polished-rod load, are: (1) weight of rods, (2) dynamic rod load, (3) rod friction, (4) stuffing-box friction, (5) weight of oil, (6) dynamic oil load, (7) friction of oil column, (8) plunger friction, (9) pressure on plunger due to fluid level in hole, (10) load on rods caused by pumping on downstroke. Of these loads, 9 and 10 will subtract on the downstroke, since they act upwards and tend to reduce the load in the rods. Since friction reverses itself every stroke so as to oppose motion, the friction forces likewise tend to reduce the polished-rod load on the downstroke, whereas they increase it on the upstroke.

If it were a matter of adding algebraically these components of the polished-rod load, the interpretation of cards and the determination of the most advantageous operating conditions would be an easy matter, but the problem is complicated by many factors, of which the following three are probably the more important:

1. A force cannot be transmitted along the sucker rods or through the oil column with a velocity greater than that of the velocity of sound in the material.
2. The oil load cannot be picked up or dropped immediately by the plunger because it must move an amount equal to the tubing stretch before it can give up or support the entire load of the oil column.
3. An increasing or decreasing rod load causes a further delay in the picking up or dropping of the oil load, since the polished rod must move an amount equal to the rod stretch before the plunger starts to move.

While such things as time for the valve to close, friction in the stuffing box, standing waves of force, effect of free gas in the oil, and many similar items exert an influence on the shape of the dynamometer card and have much to do with the successful operation of a pumping rig, their influence is not so pronounced as items 1, 2 and 3. In order to show just how they influence a card, two examples have been worked out, which will take into account only the static and dynamic load of the rod string and the static and dynamic load of the oil column, considering, however, the influence of items 1, 2 and 3 on the operation of the pumping unit. In these examples, a 2200-ft. well, being pumped by a 4-in. pump with ⅞-in. rods, making eight 11-ft. strokes per minute in case 1 and 21.1 fifty-inch strokes per minute in case 2, will be used. The polished-rod motion has been taken as being simple harmonic for simplicity.

Fig. 11 shows the construction of a hypothetical dynamometer card for case 1, which corresponds to Fig. 5*a*. In this figure, the various components which go to make up the total polished-rod load have been plotted against crank position, in degrees. The rod weight and the dynamic rod load need no explanation for their construction. The oil weight carried by the rods and the dynamic oil load are the items that are principally influenced by items 1, 2 and 3. Since a force cannot be transmitted with a velocity greater than that of sound in the material, it takes at least a time in seconds equal to the length of rods in a well divided by the velocity of sound in steel, which is 16,000 ft. per second after the polished rod starts up before the plunger starts to move upward. For the case considered here, this amounts to approximately 6½ degrees movement of the crank.

For 2200 ft. of ⅞-in. rods there is approximately 1½-in. stretch for every 1000 lb. increase in load. The tubing contracts approximately ¼ in. for every 1000 lb. load removed, so that in order to pick up a

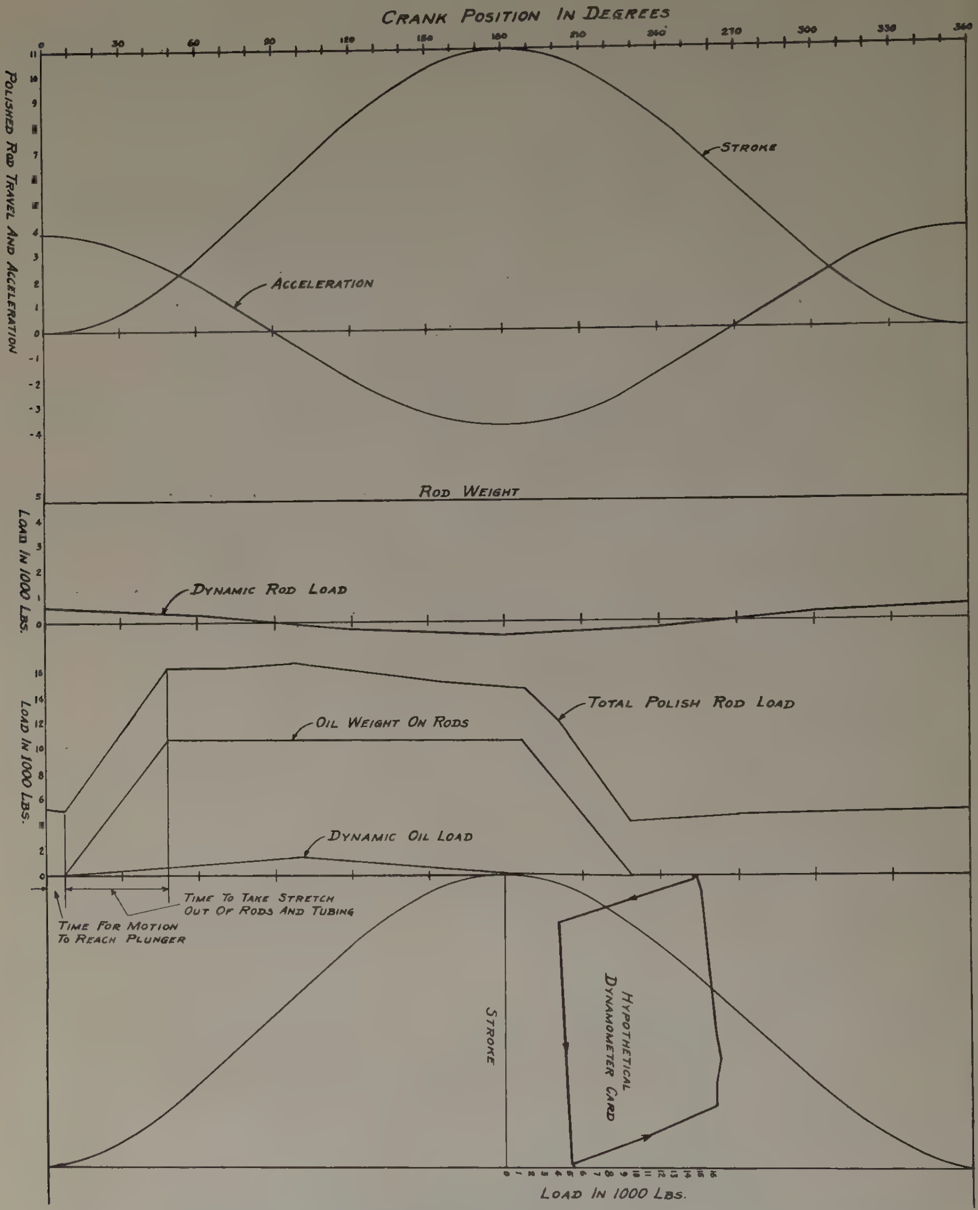

Fig. 11.—Construction of hypothetical dynamometer card for case that corresponds to Fig. 5*a*.

1000-lb. load from the tubing, it is necessary for the polished rod to move approximately 1¾ in. in order to take up the stretch in the rods and the movement of the tubing. To determine the rate at which the rods pick up the oil load, it is necessary to work out by trial and error the distance the polished rod must move in order to take the stretch out of the rods and tubing during this process of picking up the load.

Fig. 11 shows that it takes approximately 48 degrees movement of the crank before the rod string supports the entire weight of the oil column. Actually, it may take a slightly longer time because the dynamic oil load also must be considered, although in this case it has been assumed that all of the dynamic oil load is supported by the rods, for reasons of simplicity. Likewise, the rods cannot immediately drop the oil load as they start on the downstroke, because when this load is dropped off the polished rod has to move down an amount equal to the combined stretch of the tubing and change in length of the rods. The curve for the oil weight on the rods, therefore, has the shape shown in Fig. 11. The dynamic oil load after the rods start down has been assumed to be taken by the tubing. The total polished-rod load as shown is a combination of the rod weight, dynamic rod load, oil weight on the rods, and the dynamic oil load. The hypothetical dynamometer card is constructed by projecting the total polished-rod load down to the polished-rod position curve and thence to the load in 1000 lb. The card as constructed for this case, where the many factors outlined before have been neglected, has the same shape as the card shown in Fig. 5*a*.

The other item that has a great influence on the size of the card is the free gas in the oil column. The presence of free gas in the oil column results in a reduction of the oil weight carried by the rod and also probably changes the velocity with which the force can be transmitted through the oil column. It is probable that the velocity with which the force is transmitted will approach that of the velocity of sound in gas, which is of the order of 1000 ft. per second, as the amount of gas increases.

Fig. 12 shows the construction of cards for a well with the same size of pump, same well depth and polished-rod travel, but with different speeds and strokes. The curves shown with the solid line are for a 50-in. stroke at 21.1 strokes per minute. The time between the polished-rod movement and the plunger movement remains the same but the angle through which the crank turns before the plunger starts to move increases in this case to approximately 17½. This, of course, is the result of the higher crank speed, which occurs in a part of the stroke during which there is no area to the card and which, of course, becomes ineffective in producing oil.

The second case considered is indicated by dotted lines. In this the stroke has been kept the same but the speed has been increased

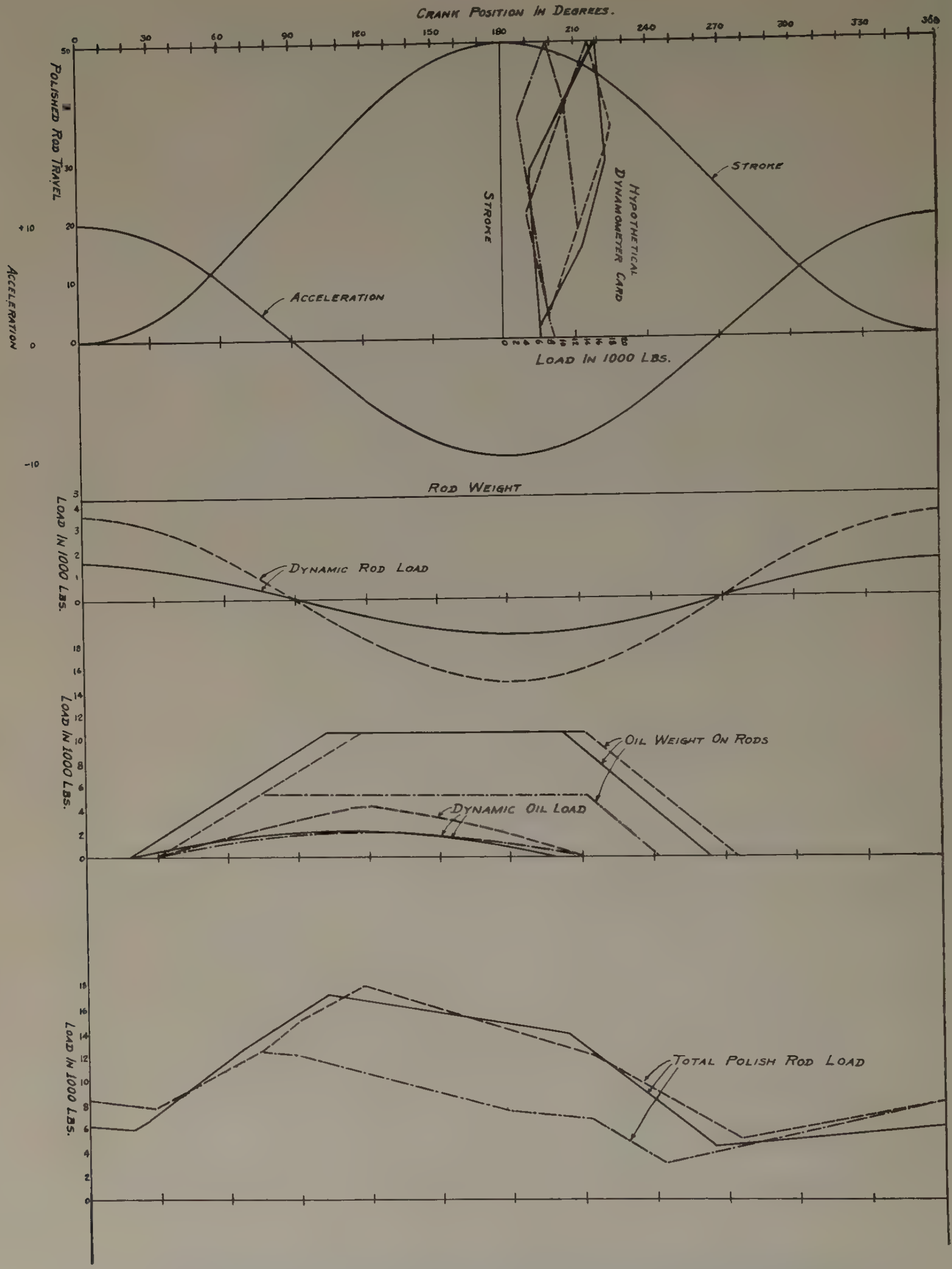

FIG. 12.—CONSTRUCTION OF CARDS FOR WELL WITH SAME SIZE OF PUMP, SAME WELL DEPTH AND POLISHED ROD TRAVEL BUT DIFFERENT SPEEDS AND STROKES.

50 per cent, or is now 31.6 strokes per minute. The dynamic rod load is therefore increased 125 per cent. The time before the plunger starts to move is further increased to approximately 34° of crank travel and results in a still larger lag. The total load curve for this condition shows only about 600 lb. increase in the peak load, although the dynamic load has increased approximately 2000 pounds.

The oil-load curves indicate that the effect of increase in the speed results in a further lag in the picking up of the oil load and throws the position of the stroke at which the entire oil load is supported by the rods to a point at which the dynamic rod load becomes negative, and this will therefore tend to reduce the peak load. However, since the dynamic oil load is increased, the net result will be an increase in total load. If the dynamic oil load is small, which occurs if a large amount of gas is present in the oil column, the peak load may actually be reduced by increasing the operating speed.

The third case shown on this figure, by the dot-dash lines, is one in which half the oil column has been assumed to be occupied by gas. It has been assumed that the velocity of sound in the oil column remains the same as before, which is about 4000 ft. per second. The resulting card shows the peak load to occur before the middle of the stroke and the entire shape of the dynamometer card changes.

The hypothetical dynamometer cards shown in Figs. 11 and 12 have been constructed on very much simplified hypotheses, but it is believed that they explain to a great extent the form of the dynamometer card, and show why such a wide variation in the form of the card is encountered in practice.

To interpret a dynamometer card, it is often necessary to have been present when the card was taken, because a loose bearing, tight stuffing box, slipping clutch or belt, an improperly operated engine or other part of the rig will introduce variations in the card, which cannot be understood by one who was not present and who does not know the cause of the variations.

The gradual accumulation of information showing the effect on the card of various operating conditions will do much to increase the utility of dynamometer cards. While the pumping system appears to be rigid, it is actually relatively elastic, and its operation must be analyzed by the mechanics of elastic bodies rather than by the mechanics of rigid bodies.

Fundamentals of Casing-joint Design and Field Application

By James B. Graham* and Earle E. Smith†

(New York Meeting, February, 1935)

The value of all minerals produced in the United States for the years 1930 to 1932 averaged $3,460,000,000 annually, according to Bureau of Mines reports. Of this amount, approximately $1,280,000,000 represents nonmetallic substances, such as petroleum, gas, sulfur and salt produced as fluids. Thus, about 37 per cent of the country's mineral wealth is procured through wells drilled in the earth, which require casing to keep them open throughout their life.

Deep well drilling has increased greatly in the last few years. Several strings of casing have been set deeper than 9000 ft.—one, a string of 7⅝-in. O.D. casing, 10,301 ft. long, run in a well drilled by the Gulf Production Co. in West Texas, holds the record up to this time. These are longer strings than were contemplated when the American Petroleum Institute Specifications were adopted 10 years ago, therefore it is necessary to consider whether the present joint standards are adequate for such strings, or for even longer strings that may be called for in the future. Petroleum engineers are asking:

Is there a possibility that stronger joints can be designed without going to stronger and more costly steels than offered in present specifications?

Without sacrificing too greatly the tensile properties of the joint, can its design be changed to allow more clearance in the open hole below the next larger string of casing, and thus avoid costly underreaming?

What can manufacturers offer for drilling through heaving shale?

Fundamentals of the Problem

During the last few years considerable study has been given to casing joints and their limitations, and since attention must be given to this subject by those who will be required to drill deeper holes, it is timely to review the fundamentals of the problem. These will be recognized generally as the following:

1. No threaded joint can be stronger than the area of metal under the root of the first perfect thread, and this area must be large enough

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to carry the entire weight of the string with a reasonable factor of safety, preferably a minimum of 2½.

2. The joint must be watertight.

3. It must be foolproof to the extent that it cannot be easily damaged in handling or running, but it should be of a type that can be easily repaired if it is damaged.

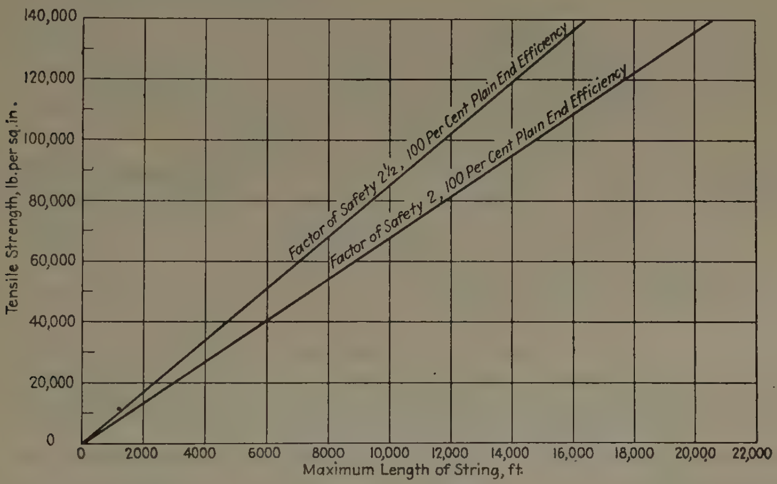


FIG. 1.—MAXIMUM LENGTH OF STRING FOR STEEL OF VARIOUS TENSILE STRENGTHS.

4. The joint must offer high resistance to bending stresses and must stand a reasonable amount of deflection without leaking.

5. The joint should lend itself to rapid production in the mills and it should be acceptable to a large number of users.

The collapsing strength of casing is also of great importance. However, sufficient strength to resist almost any external hydrostatic pressure can be obtained by increasing the wall thickness of the pipe, or the effective pressure can be brought within a safe range by the use of cement to fill the annular space between the drilled hole and the casing.

Economic Limitations of Higher Tensile Steels.—The limitations of steel should be considered, because any continuous string of steel of uniform cross-section will cease to be self-supporting if the length is increased beyond certain limits, that are directly proportional to the unit strength of the steel. Fig. 1 shows that notwithstanding the use of safety factors much lower than those approved for general construction, drilling operations are gradually approaching the limits of depth attainable with existing commercial grades of pipe steel. In the American Petroleum Institute Specifications, which are universally accepted, the classes of steel most suited to casing are grade C, with 75,000 lb. per sq. in. minimum ultimate tensile strength, and grade D with 95,000 lb. minimum. With a safety factor of 2, steel of 105,000 lb. average tensile could be set at approximately 15,442 ft. if the joints were as strong as the body of the casing. There would be little difficulty in forging seamless tubular sections strong enough to run to much greater depths, but it is the joining together of these sections in long strings that presents practical difficulties in keeping the dimensions of the joint within desirable limits and yet approaching, as closely as possible, the strength of the full casing section.

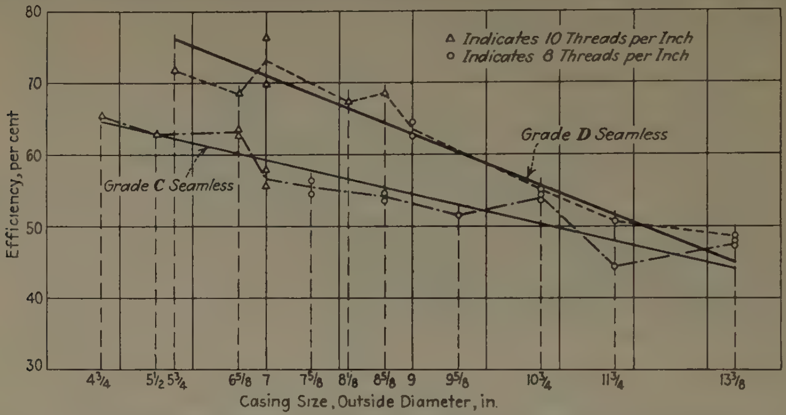


FIG. 2.—JOINT EFFICIENCIES FOR A.P.I. GRADE C CASING AND GRADE D CASING (LONG THREADS AND COUPLINGS). EFFICIENCY BASED ON PLAIN END METAL AREA.

Joint Efficiencies Are Determined by Full Section Tensile Tests.—The ratio of the joint strength to the strength of the full casing section represents the efficiency of the joint. Such factors as the elasticity of the joint members, the extent of the friction between the thread flanks and the effects of variation in pitch and taper of the commercial product, make difficult the expressing of joint strength by a mathematical formula. In this analysis, therefore, the efficiencies have been determined by actually pulling to destruction numerous specimens of commercial and experimental joints. Fig. 2 shows curves representing joint efficiencies for grade C and grade D A.P.I. casing. Each point on the curves represents the average of six tests, comparing the strength of joint to the strength of plain end section.

TYPES OF CASING THREADS

Standard A.P.I. casing is equipped with threaded and coupled joints of the same design as those in general use in the Mid-Continent and California oil fields at the time the specifications were adopted. The threads are of the form called American V-type, or Briggs' form. The depth of these threads is 0.8 times the pitch.

Fig. 3 shows a section of a conventional casing thread, also a section of a joint with the coupling completely made up on the thread. The area of metal in the cross-section directly below the first perfect thread (indicated on the drawing by *A*) represents the maximum strength that could possibly be developed. The efficiency of such a joint, when fitted with a coupling at least as strong as the threaded end of pipe, ranges from 45 to 75 per cent, depending on the length of the thread, the size of the pipe and its wall thickness.

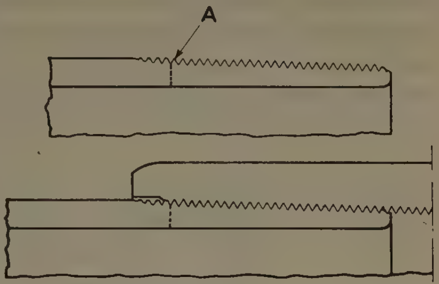


Fig. 3.—Section of conventional casing thread and section of joint with coupling completely made up on thread.

Area of metal in cross-section directly below first perfect thread (*A*) represents maximum strength that could be developed.

Other types of threads are occasionally used on casing. The Acme thread has a depth of ½ the pitch plus 0.010 in. Another, the rounded V-thread, has a depth approximately 0.57 times the pitch, or a little shallower than the Acme. Therefore, in cutting the American V-thread a slightly greater amount of metal is removed than in making any of the other types. Fig. 4 illustrates five types of threads, which include the buttress thread and a modification of the Acme thread, as well as those mentioned. On threads of the square or buttress types, the angle of the flanks in contact is generally made about 5° to a line perpendicular with the axis of the casing, while on the conventional threads with 60° included angle this bearing surface is 30°. Thus, with the square type

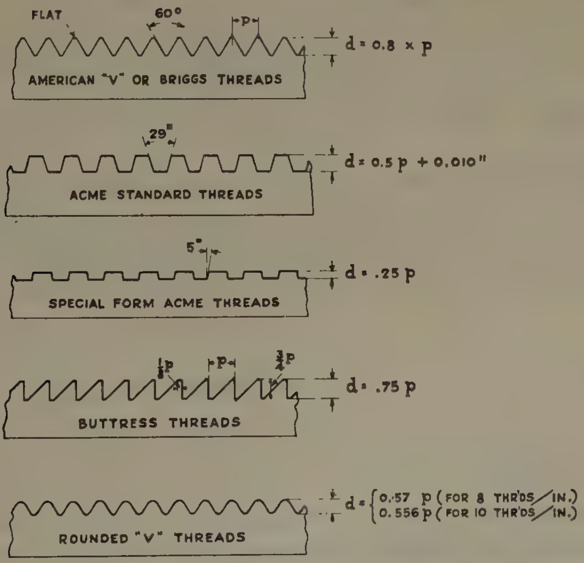


Fig. 4.—Five types of threads.

of threads the tension forces produce a smaller component acting inward on the threaded end of the casing. Part of the theoretical gain from the smaller flank angle on the square thread is lost, however, because of the elasticity of the threaded end, which, under great tension, elongates slightly and contracts diametrically, regardless of the type of thread in contact, and there remains also much of the same tendency for the threads to turn over, or deform, slightly on the crests, hastening the failure of the joint by permitting the threaded end to jump out of the coupling.

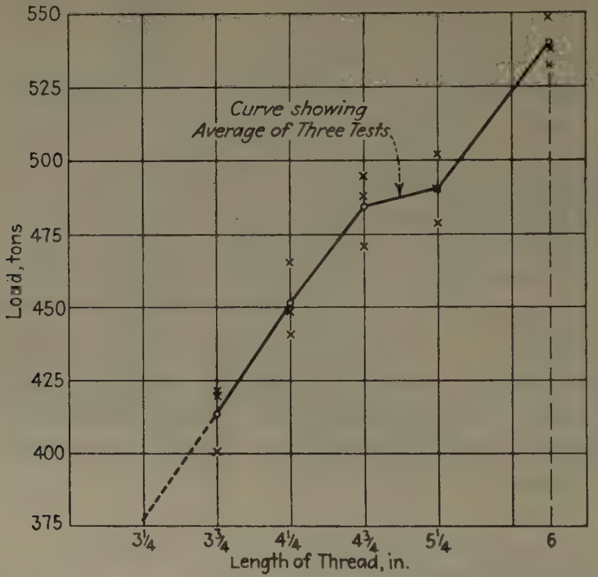


FIG. 5.—INCREASE IN STRENGTH OF JOINT THAT RESULTS FROM INCREASED LENGTH OF THREAD.

Methods of Increasing Joint Strength.—A longer thread will increase the joint efficiency. This is true because many of the joints with relatively short threads permit the threaded section at the end of the pipe to contract and the thread pulls out of the coupling. The curve in Fig. 5 indicates the increase in the strength of a joint that results from increased length of thread and such test results were the basis for designing longer threads and couplings for grade D casing.

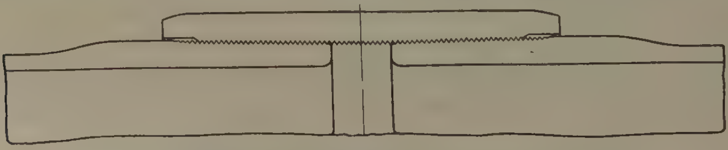


FIG. 6.—CONVENTIONAL EXTERNAL UPSET CASING JOINT.

It is obvious that the strength of a joint can be increased by the use of higher tensile steel in the casing. While this is an effective method of obtaining greater joint strength, it does not increase the ratio of strength existing between the joint and the plain casing section. At present it does not seem necessary, and probably would not be economical, to use steel with an average tensile strength over 105,000 lb. per sq. in. for casing material.

In threading any joint, a part of the casing wall must be cut away, therefore it is impossible to develop 100 per cent joint efficiency without upsetting.

Fig. 6 represents a casing joint with the conventional external upset that provides increased metal area at the first perfect thread. The greatest objection to the use of an upset is the increase in the joint diameter, and, consequently, the reduction of the clearance between strings. This means larger size and heavier wall casing will be required to finish the well with the same size of hole. Internal upsets are not practicable, as the full bore of the casing is required for the free passage of drilling tools and swabs.

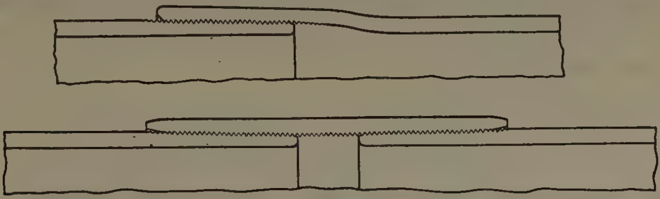


Fig. 7.—Inserted casing (*a*) and threaded and coupled casing (*b*).

Judging from joint designs that have been placed on the market during the last few years, there is a place for a joint that will give added strength without taking up too much of the drilled hole, or conversely, one that will give added clearance without sacrificing too much strength. By using two designs of joints in one hole, joints with increased strength can be used at the top of the string and those with increased clearance can be used on the bottom, but it is virtually impossible to obtain in one design the full advantages of both joints.

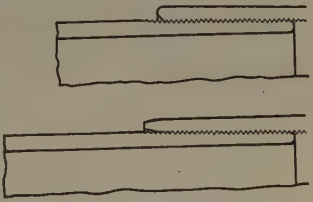


Fig. 8.—Same as Fig. 7 blocked to show similarity of connecting portions.

Joint Designs that Give Increased Clearance.—There seems to be a fairly general idea that inserted joints, that is to say, threaded joints similar to the bell and spigot design illustrated in the upper half of Fig. 7, will give greater clearance with less sacrifice of strength than will threaded and coupled joints. Obviously, the maximum strength of the joint depends on the area of metal at the root of the first perfect thread of the bell end of the pipe as well as of the first perfect thread of the inserted end. On the bottom half of this figure is shown a threaded and coupled joint with a coupling the same thickness as the bell. In Fig. 8

the right-hand portion of the two joints is blocked out, which makes clearer the point that there is no essential difference in the connecting portions of the two designs. The material in the bell is no stronger than the steel in the body of the pipe; but the coupling shown in the lower drawing could be made of higher tensile steel and therefore made thinner, or, in other words, greater clearance could be obtained than with the inserted type joint without sacrificing joint strength. This advantage in the use of a coupling obtains regardless of the type of thread employed.

Since couplings can be made stronger, and consequently thinner, the pitch diameter of the threads on the pipe can be increased and the strength of the joint correspondingly increased without sacrificing clearance. This requires the use of an external upset but in a way that will not sacrifice clearance.

Use of Alloy-steel Casing Couplings

The use of heat-treated alloy-steel casing couplings is a development of the last four years. They were first used by the Standard Oil Co. of California to gain clearance on the lower part of casing strings run at Kettleman Hills. By gaining clearance and thus avoiding underreaming in setting these oil strings of casing, it is reported that $14,000 per well is being saved. We will show later the possibilities of using these couplings to gain maximum clearance. First, we wish to show how such couplings can be used to develop 100 per cent joint efficiency without sacrificing clearance over that now existing in regular combinations of A.P.I. casing.

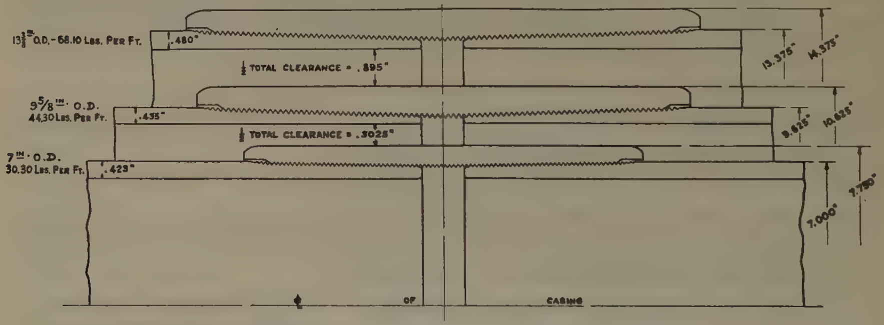


Fig. 9.—Alloy couplings on upset casing.

Alloy Couplings on Upset Casing.—Fig. 9 illustrates the 13⅜-in. O.D., 9⅝-in. O.D. and 7-in. O.D. grade D combination, which is most commonly used for wells 6000 ft. and deeper. Note the minimum total clearance is 1.005 inches, which, apparently, has proved to be sufficient for the smaller strings.

Fig. 10 illustrates the same combination, but with the casing upset sufficiently to develop the full strength of the plain end pipe. The use of heat-treated alloy-steel couplings on upset casing permits holding the joints to the same outside diameter, as previously illustrated on plain casing. These couplings may appear somewhat thin to those who have been accustomed to couplings made from regular grades of steel; however, the manufacture of these high-tensile couplings has passed beyond the experimental stage and we believe the diameters may be reduced still further if this becomes necessary, especially for use on the lower portion of casing strings. With this type of joint, 7 in. O.D. 30.30 lb. grade D casing could be set at a depth of 12,400 ft. with a safety factor of 2½, and if safety factors as low as those used on some recent long strings of casing are considered satisfactory, where the casing was run by using float valves in the string, it could be set at depths as great as 15,000 feet.

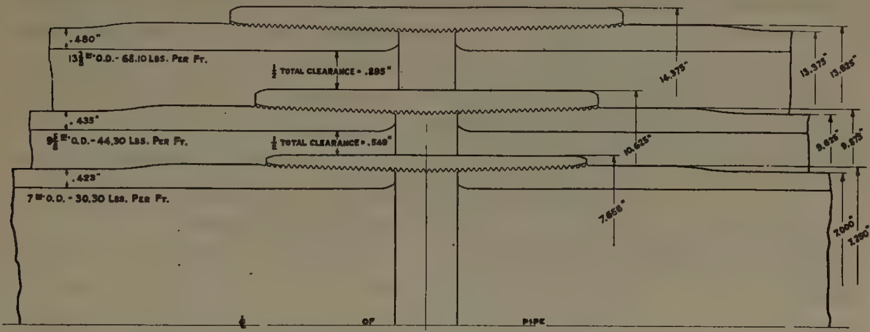

.480"
13⅜" O.D.-68.10 Lbs. Per Ft.
½ Total clearance = .295"
14.375"
13.375"
13.625"
.435"
9⅝" O.D.-44.30 Lbs. Per Ft.
½ Total clearance = .549"
10.625"
9.625"
9.875"
.423"
7" O.D.-30.30 Lbs. Per Ft.
7.656"
7.000"
7.250"
℄ of pipe

FIG. 10.—SAME COMBINATION AS IN FIG. 9, WITH CASING UPSET TO DEVELOP FULL STRENGTH OF PLAIN END PIPE.

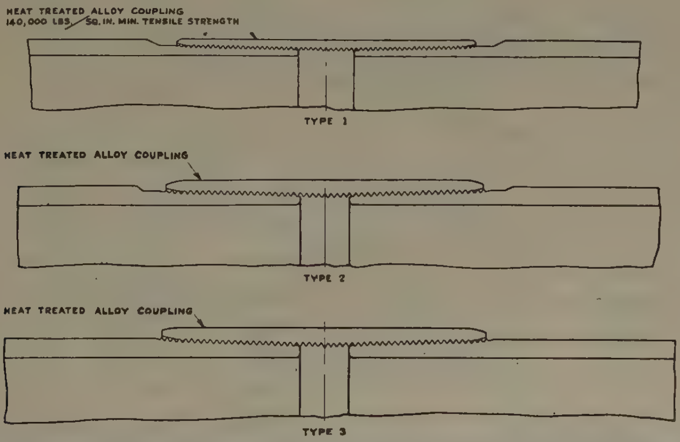

Heat treated alloy coupling
140,000 Lbs./Sq. In. Min. tensile strength
Type 1
Heat treated alloy coupling
Type 2
Heat treated alloy coupling
Type 3

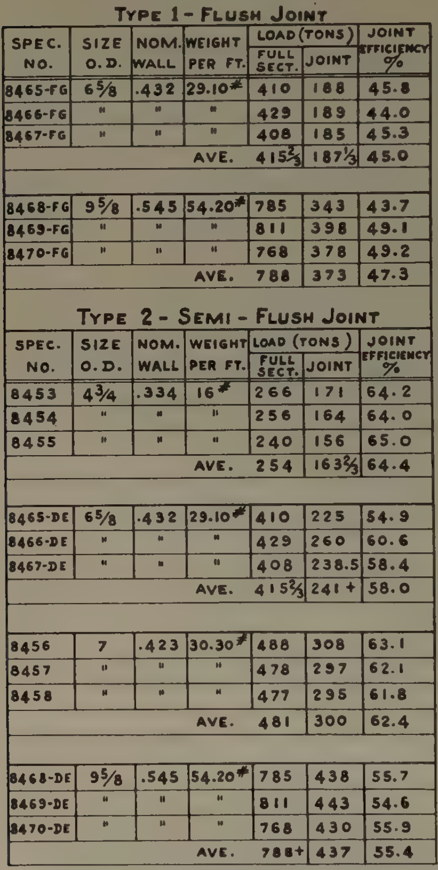
FIG. 11.—FLUSH COUPLING JOINT (TYPE 1), SEMI-FLUSH JOINT (TYPE 2) AND JOINT THREADED TO STANDARD PITCH DIAMETER AND FITTED WITH ALLOY-STEEL COUPLING (TYPE 3).

This is a conventional joint which can be made in the regular line of production at the mill and one that would be easy to recondition in field shops when necessary.

Alloy Couplings on Casing Not Upset.—Occasionally, clearance becomes more important than joint strength. This is true where underreaming the open hole below the next larger string of casing is to be avoided. It is not necessary to depart from the conventional joint to meet these conditions, provided heat-treated alloy-steel couplings are used.

Fig. 11 illustrates: (1) a flush joint, (2) a semi-flush joint, and (3) a joint threaded to standard pitch diameter and fitted with an alloy-steel coupling.

The usefulness of a flush joint is very limited. It is the weakest of all types of joints regardless of the kind of thread adopted for it, and generally there is enough clearance in the well to accommodate a stronger joint. Type 1 shows an average joint efficiency of 46 per cent with relation to the plain pipe. This is about 8 per cent higher than is usually obtained with the conventional type of flush joint; on some of the larger sizes the efficiency is as much as 15 per cent greater. Type 2 has an average joint efficiency of 58 per cent. This type of joint has practically all of the advantage of a flush joint; in fact, some operators hold the opinion that it is easier to free a "frozen" string of pipe fitted with couplings, since the passing of the couplings enlarges the hole and thereby eliminates part of the friction. Type 3 has the same strength as the long thread and coupling joint now used on grade D casing. The cost of the alloy couplings is relatively high but often they effect an ultimate saving due to the greater clearance afforded.



TYPE 1 - FLUSH JOINT

SPEC. NO.	SIZE O.D.	NOM. WALL	WEIGHT PER FT.	LOAD (TONS)		JOINT EFFICIENCY %
				FULL SECT.	JOINT	
8465-FG	6⅝	.432	29.10#	410	188	45.8
8466-FG	"	"	"	429	189	44.0
8467-FG	"	"	"	408	185	45.3
			AVE.	415⅔	187⅓	45.0
8468-FG	9⅝	.545	54.20#	785	343	43.7
8469-FG	"	"	"	811	398	49.1
8470-FG	"	"	"	768	378	49.2
			AVE.	788	373	47.3

TYPE 2 - SEMI - FLUSH JOINT

SPEC. NO.	SIZE O.D.	NOM. WALL	WEIGHT PER FT.	LOAD (TONS)		JOINT EFFICIENCY %
				FULL SECT.	JOINT	
8453	4¾	.334	16#	266	171	64.2
8454	"	"	"	256	164	64.0
8455	"	"	"	240	156	65.0
			AVE.	254	163⅔	64.4
8465-DE	6⅝	.432	29.10#	410	225	54.9
8466-DE	"	"	"	429	260	60.6
8467-DE	"	"	"	408	238.5	58.4
			AVE.	415⅔	241 +	58.0
8456	7	.423	30.30#	488	308	63.1
8457	"	"	"	478	297	62.1
8458	"	"	"	477	295	61.8
			AVE.	481	300	62.4
8468-DE	9⅝	.545	54.20#	785	438	55.7
8469-DE	"	"	"	811	443	54.6
8470-DE	"	"	"	768	430	55.9
			AVE.	788+	437	55.4

FIG. 12.—RESULTS OF TENSION TESTS ON TWO TYPES OF JOINTS, GRADE D OF A.P.I. SPECIFICATION.

Fig. 12 shows the results of tests on the flush and semi-flush types of joints. In each test the specimens were cut from the same length of pipe so that comparisons could be made directly and without taking into consideration slight variations in tensile properties and wall thickness that might affect the results if test specimens were cut from different lengths.

We have mentioned that the joint strength could be increased by upsetting or by increasing the tensile strength of the material. The latter can be done only at great expense, since the price of a suitable alloy steel in the form of blooms is approximately five times as high as grade D steel, and further, the production of such pipe would require new and radically different heat-treating equipment in which the pipe could be quenched vertically in a bath of oil. However, a short section of casing made of heat-treated alloy steel could be welded to the end of the full section of casing that has been upset. Such a joint, illustrated in Fig. 13, will give 100 per cent efficiency based on the plain end strength of grade D casing, and the outside diameter of the joint will be less than that of the standard joints for threaded and coupled casing not upset. The efficiency of this type of joint depends largely on the character of the weld, and the practicability of its manufacture depends on studies now being made in the welding of alloy steels. Even if the weld is assumed to be 100 per cent, the metal near it might be affected by the heat of welding to the extent that it would not be as strong as the pipe. The use of a slight upset, as indicated, would develop the full strength of the pipe wall, even though the welds at the upset ends were only 90 per cent efficient. This joint uses conventional threading practice and meets all fundamental requirements for casing joints.

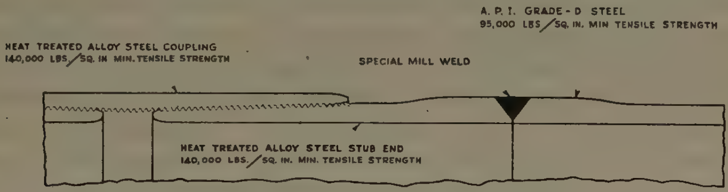

A. P. I. GRADE - D STEEL
95,000 LBS/SQ. IN. MIN TENSILE STRENGTH
HEAT TREATED ALLOY STEEL COUPLING
140,000 LBS/SQ. IN MIN. TENSILE STRENGTH
SPECIAL MILL WELD
HEAT TREATED ALLOY STEEL STUB END
140,000 LBS./SQ. IN. MIN. TENSILE STRENGTH

Fig. 13.—Short section of casing welded to end of full section of upset casing.

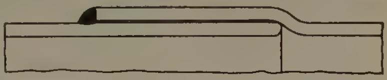


Fig. 14.—Welded slip joint.

Welded Joints Suitable for Larger Sizes

In the larger sizes, slip-joint casing, as illustrated in Fig. 14, is used to a considerable extent, particularly in California. While much depends on the personal element in welding this joint, it will, on the average, show a higher percentage of efficiency than a threaded joint. For convenience in stabbing, and because it is necessary to weld the casing in a vertical position, the slip-joint type is highly desirable, although the butt-welded joint is stronger, no doubt. Where casing may have to be pulled and rerun, there is a great disadvantage in using welded joints, and they give no gain in clearance on sizes 10¾ in. and smaller.

V-type Threads Hold High Pressures

The second fundamental of joint design is that it must be leakproof. No gain in other respects will justify sacrificing this feature or taking a chance with any design that does not offer full assurance against leakage. Tapered threads of the conventional V-type have been tested for their tightness through many years of service, and are holding some of the highest gas pressures encountered in drilling. If reasonable care is used in cleaning the threads and the joint is made up with a good zinc lubricant, this type of thread will withstand pressures that produce stresses in the full casing walls approximately equal to the yield point of the steel.

In making up a taper-threaded joint that has the American V or Briggs' form of thread, a stress is produced in both the threaded end of the pipe and the coupling that forces the flanks of the threads together, thereby making a pressure-tight fit. The crests and roots of the threads are essentially the same shape, thus making a close fit. The Acme or square-type threads, as previously pointed out, have a very small component of force to produce tightness between the flanks of the threads, and it is generally agreed that a joint with this form of thread must be supplemented by a pressure seal of some kind. This feature can be worked out as a square or tapered shoulder at the end of the threads and will receive consideration later.

Simplicity in Design Preferred for Field Use

The third point is that the joint must be foolproof, so that with ordinary care in shipping, hauling and handling it is not rendered unserviceable. There is always the possibility that the casing might be dropped and an end knocked out-of-round. If the coupling of a conventional joint is damaged, it can be removed and replaced with another. If the thread is damaged, it can be repaired in any local shop that has a fairly competent mechanic, and a lathe or threading machine. Where joints of the bell end type are used, any damage to the bell end would require a complete refinishing for which special equipment is required.

There is also a possibility of damage in making up joints. When high-tensile steels are screwed together, particularly if they have not been heat-treated, it is essential that a nonferrous metal be interposed in some way between the two mating surfaces. To prevent galling, it is now standard practice to electrogalvanize the threads of casing couplings. Threads in the bell end type of joint, being integral with the pipe, do not lend themselves readily to the practice of electrogalvanizing. In making up joints for the high pressures that are incidental to deep drilling, the joints must be made considerably tighter than is necessary in shallower wells, and in such cases electrogalvanizing is an important factor in preventing damage to the threads.

The rise in temperature and the general behavior of joints with conventional threads give a clear indication of their reliability in tension and of their pressure tightness. Special square threads do not assure pressure tightness by the contact on the flanks of the threads, and therefore the fit on the flanks does not give a true indication of any likelihood of leakage. Careful inspection must be given to each pressure seal before making up the joint in order to detect any abrasions from handling or any out-of-roundness.

JOINTS MUST RESIST BENDING

The fourth requirement is that the casing must offer high resistance to bending. Fig. 15 shows the results of deflection tests on various types of joints. The long threads and couplings of the conventional type now generally used on grade D casing show the best results. The length of the coupling and the length of the threads in engagement have an important bearing on the resistance to deflection.

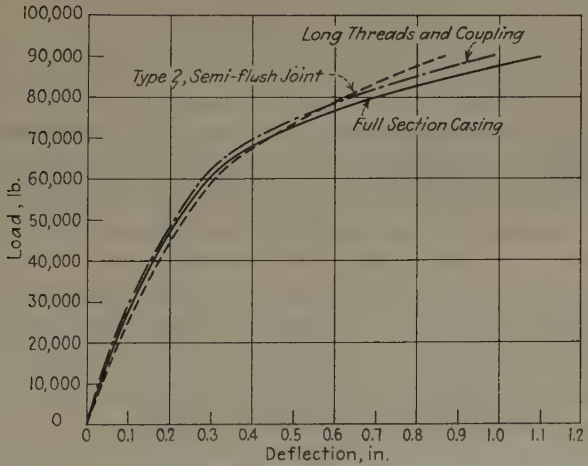


FIG. 15.—COMPARATIVE BENDING TESTS ON SEAMLESS CASING, 6⅝ IN. O.D., 29.10 LB. GRADE D, WITH 64-IN. SPAN BETWEEN SUPPORTS AND LOAD APPLIED AT CENTER.

It is also necessary to consider the fact that the moment a casing joint leaks it has failed for practical purposes, therefore a joint with a long thread contact that is pressure-tight has an advantage over joints with short threads or those that depend upon a narrow pressure seal. Deflection tests made while the joint is under hydrostatic pressure are now in progress, but it is unfortunate that the results are not yet available.

SUITABILITY FOR QUANTITY PRODUCTION REQUIRED

The fifth requirement is that joints must lend themselves to rapid production in the mills. The conventional casing joint is produced in threading and tapping machines, which, like machines for mass production in the automobile industry, have been perfected to the point of turning out quantity work with a high degree of accuracy. A joint that requires a shoulder seal to be leakproof must have the threads cut in accurate relation to the shoulder so that the contacting points throughout the joint will come to an exact bearing when the joint is made up. A large number of orders for this kind of special threading would require a complete change of equipment and an increase in the cost of production. It is evident that reconditioning of special joints in the field would require lathe work of a caliber not usually found in field shops; consequently special joints with intricate threading are not suited to quantity production and wide use.

CONCLUSIONS

The limit of depth to which casing made from steels in general use may be set, even with a low factor of safety, is approximately 15,400 feet.

By upsetting the ends of casing, joints can be made that will develop the full strength of the casing wall. If these upset joints are fitted with heat-treated alloy steel couplings, the outside diameter of the joints can be kept as small as that on the present standard casing, which is not upset.

Wherever it is essential to reduce joint diameters for the purpose of gaining greater clearance in the open hole, high-tensile, thin-wall couplings may be used with a minimum sacrifice of strength.

Such joints will retain, both in manufacture and in use, all of the advantages now afforded by conventional threading.

DISCUSSION

(*H. H. Power presiding*)

G. M. EATON,* Ambridge, Pa. (written discussion).—The fundamental fitness of casing joints for service can be decided most reliably by going through motion studies of the actual routine running of casing into wells. We will touch on a few of the more outstanding of the many features involved.

When the well is drilled through treacherous formation, any feature of the joint that reduces the time required to land the casing is constructive, provided that the new feature is in no way a trouble maker.

Under the best of conditions, the act of stabbing A.P.I. casing is an operation that is rather strenuous and yet precise, but when the situation is complicated by high wind, low temperature, sleet, or when the derrick floor is inches deep in overflowing mud, accurate stabbing of the A.P.I. joint becomes very difficult. The short A.P.I. joint must be stabbed on the feather-edged ends of the threads. The stabbed joints must then be lined up by eye and the threads must be engaged with sufficient care to avoid cross-threading. With the long A.P.I. threads, the sharp crests of a few male threads must pass the equally sharp crests of the female threads without any damage, and the weight of the stabbed length must be carried in the stabbed position on the thin tips of a few threads.

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* Director of Research, Spang, Chalfant & Co.

One can only marvel at the skill exhibited by a trained casing crew; nevertheless, a great many joints of A.P.I. casing are damaged in stabbing to an extent that requires the laying down of the casing. This costs money, causes delays, and is avoidable. Simplified stabbing is therefore worth going after.

The diameter clearance between the ends of the male and female A.P.I. threads is small even with the long threads. This stabbing clearance can be increased by making the thread taper much steeper, and by making the threads shallower, which gives the stabber a larger target at which to shoot. By replacing the sharp-pointed, fine-pitched V-threads of the A.P.I. joint with sturdy shallow threads having flat crests parallel with the axis, a joint is secured in which the male member, as stabbed, enters deeply into the female member. As the flat thread crests pass each other, the stabbed length of casing is automatically pulled into alignment without damage to the threads, and in the stabbed position the weight of the stabbed length is carried on a large number of threads, amply strong to support the weight without damage. The stabbed joint is thus always aligned and the threads are engaged and ready to spin with complete assurance that the thread has undergone no damage that will cause galling while the joint is being made up.

The deep entry of the male into the female in combination with a thread of coarser pitch than that of the A.P.I. joint reduces the number of turns the spinning rope must give to the stabbed joint low enough to avoid the necessity of slacking off the rope when the spin is half done in order to pull the turns wrapped around the casing down closer to the joint, as is usually necessary with A.P.I. casing joints.

The combination of characteristics of a modified casing joint carries with it the much greater advantage of requiring only a small number of tong yanks to drive the joint home, which saves time. It has the additional advantage of making a welcome reduction in the work demanded of the casing crew. It is entirely practical to make a joint that will require only one-third as many tong yanks as the average A.P.I. casing. Furthermore, there is always the question of how hard the tongs should pull on the A.P.I. joint in order to come between the limits of a joint that may leak because of undertonging, and a joint that may be galled and therefore leak because of overtonging. This question is avoided when the joint is provided with a definite stop which provides a witness mark to indicate when the joint is properly made up, and which makes it a physical impossibility to damage the joint with the size of tongs and jerk line ordinarily employed. The natural type of stop to employ is the "end to shoulder" engagement universally used for the pin and box connection of tool joints.

Many improperly made up joints of A.P.I. casing are run down the hole and the operator never knows whether or not these joints are tight. If gas pressure builds up at the braiden head, the operator is usually at liberty to guess whether the leakage is occurring through defective casing joints or is the result of a defective job of cementing. One leaking joint in a string makes a leaky casing.

Complete freedom from galling during make-up is doubly assured by using a thread in which there are liberal clearances on the thread flank, and also between the crests of the thread of one of the members and the corresponding thread roots of the other member. These clearances provide room into which, if incipient galling results from extreme accidental damage of the threads, the plastically displaced metal can flow without danger of building up a lump gall. It is evident that a joint employing the features mentioned can be stabbed and made up in less time than is possible with the A.P.I. thread.

The square shoulder of the A.P.I. coupling prevents the practical running of A.P.I. casing through pressure packing. The square shoulder also always involves the possibility of hanging up in the open hole. With a streamlined joint it is entirely practical to run casing through pressure packing, and the possibility of open hole interference is reduced.

After casing has been landed, the cementing demands attention, and since this is still a somewhat uncertain operation, anything that assists in the free flow of the cement up around the outside of the casing is important. A streamlined exterior contour of a casing joint reduces turbulence in the cement and therefore offers a desirable improved tendency. This contour also reduces the pressure required to break circulation.

After the casing has been set and cemented, it is important that it remain tight against hydrostatic pressure. The characteristics of the thread which have been outlined to this point, and which are essential in order to gain the advantages to which reference has been made, result in a thread that offers no resistance to leakage under hydrostatic pressure. In fact, only by relieving the casing thread of the duty of leak resistance is it at all possible to reap the advantages mentioned.

Obviously, an independent leak-resistant seal is necessary. This can be made most effectively by the use of mating conical seats in the male and female members. While the end to shoulder engagement is in itself an effective seal in a joint that has been tonged home properly, it is not safe to rely upon this. A joint tonged insufficiently to bring the stop into contact would be wide open for leakage as far as this "end to shoulder" seal is concerned. But a conical seal having a taper about the same as that of the threads insures reliable leak resistance, even when the end to shoulder engagement is open by a few thousandths of an inch. It is advisable to add a non-engaging protecting nose to guard the male seal against damage.

To insure successful fishing or recovery of casing from a well, the joint should have the highest practical tension efficiency. A careful study of all the points involved in determining this maximum practical tension efficiency shows that it is reached by a joint strong enough to put a small permanent stretch into the normal body of the casing. But the joint must fail under tension before the normal body breaks, because material necking down occurs when casing with proper ductility is pulled to destruction. The necked-down end would make an ugly fishing job.

The joint that results from an analysis of the fundamental requirements for casing is peculiarly free from accidental damage, owing in part to the sturdy thread form. But it is also due to the selection of those thread crests and roots that are best protected, to perform the duty of hard bottoming in the made up joint. The female thread crests bottom in the male roots, and the location of these crests and roots gives them adequate protection from all ordinary damage. Reasonable scarring of the male thread crests does no harm, as these crests make no contact with the female roots. This all means that comparatively little repair is necessary with this type of joint.

The last service requirement to which we call attention at this time is that the joints of any given size must be strictly interchangeable and must be adequate in all particulars after repeated and indiscriminate make-up. This demands that the joint lend itself to simple and accurate gaging, which will determine with full assurance the fitness of the casing to perform the functions for which it is produced. The new casing to which we have referred meets this fundamental completely.

W. M. Frame,* Ambridge, Pa. (written discussion).—Mr. Graham and Mr. Smith have shown that for some applications it is desirable to have available casing with the coupling O.D. smaller than the A.P.I. coupling. They have described how the coupling O.D. can be reduced by the use of high-strength couplings, but with some sacrifice in joint efficiency in tension.

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* Mechanical Engineer, Spang, Chalfant & Co.

Now let us attack the problem from an entirely different viewpoint and see whether it is possible to obtain both decreased coupling O.D. and increased joint efficiency.

First, consider the manner in which the A.P.I. joint fails in tension. Tensile loads are resisted by the thread flanks, which are at 60° with the axis of the pipe. Because of the wedging action of these thread flanks, the coupling tends to expand radially and the pipe end tends to contract radially. As the tensile load is increased, some value is reached where relative movement between the mating thread flanks occurs because of the wedging action. With movement, the condition rapidly becomes worse until suddenly the pipe end snaps out of the coupling. Relative movement of the mating thread flanks occurs because the 60° flank angle is greater than the frictional angle of repose of the surfaces. If the flank angle is decreased until it is less than the angle of repose of the surfaces, no movement could occur because the flanks would be locked together by friction.

We have found by a considerable amount of experiment that an included flank angle of 12° is well within the angle of repose of the surfaces. Of course, it is out of the question to try to make a V-thread with an included flank angle of 12°. So, in order to be practical, threads with small included flank angles must be of a modified Acme form. With respect to tension, this modified Acme thread is almost ideal. The thread flanks can be made with a very small included angle, so that friction holds the mating flanks firmly together under tensile loads. Therefore, the strength of the joint depends almost entirely on the cross-sectional area of the joint at the root of the thread. If this area at the critical section is equal to the cross-sectional pipe area, the joint efficiency will be approximately 100 per cent. Or the joint efficiency can be made whatever is desired within reasonable limits. The same joint efficiency can be obtained on, say, 10¾-in. casing as on 6⅝-in. casing. It is not necessary to use a heavy coupling, as in the A.P.I. joint, in order to insure low expansive deflection. Therefore, the O.D. of this joint can be made much less than the O.D. of the A.P.I. coupling and with a considerably higher joint efficiency.

Now, can a commercial pipe thread of a modified Acme form be machined accurately enough to prevent leakage? We consider it utterly impractical to attempt this, so it is necessary to provide a separate means for preventing leakage. A tapered seal at one end of the threaded portion of the joint is very satisfactory. These tapered sealing surfaces are simple surfaces of revolution and can be easily and reliably manufactured to provide very high resistance to leakage. The joint will not leak when subjected to external pressure great enough to collapse the pipe. Neither will it leak when subjected to internal pressure great enough to stress the pipe body to the yield point.

If the threads do not have to seal off the joint, it is not necessary that the thread form be extremely accurate. The thread flanks do not have to contact on both sides of the thread, because the resistance to make-up can be secured by bottoming the flat thread crests of one member in the mating flat thread roots of the other member. The other crests and roots do not have to engage.

The gaging operation is simple and reliable because only diameter and taper are involved, and with respect to the thread, it is necessary to gage only the parts of the thread that engage; namely, the crests of one member and the mating roots of the other member.

A casing joint with this Acme type of thread for strength, and with a tapered seal for reliable prevention of leakage, has four distinct advantages as compared with the A.P.I. type of joint: (1) higher joint efficiency in tension; (2) smaller joint O.D.; (3) a more uniform and reliable product can be manufactured; (4) the resistance to leakage is greater and more reliable. Any logical analysis of the casing problem must give serious consideration to these fundamental features. There are also many other important advantages.

Probably every pipe manufacturer is proud of the accuracy of his A.P.I. joints. We are proud of the accuracy of our A.P.I. joints. For many applications the A.P.I. joint is adequate, but for deep wells, where tremendous investments are involved, there is a real need for a more reliable and adequate casing joint. And this need is not necessarily limited to deep wells. The range of application of the casing joint with the modified Acme thread and the separate seal can be determined only by wide field experience.

J. B. Graham (written discussion).—Mr. Eaton and Mr. Frame have presented the merits of a special joint. We have studiously avoided criticizing any particular product, but have tried to present the fundamental requirements in such a way that engineers can select from the various joints offered the type that best meets their problem. However, it will be necessary for us to make some comment upon the discussions, lest we be understood as agreeing with them that such a radical departure from A.P.I. standards as they advocate is necessary.

Everyone recognizes the value of an upset in strengthening casing joints. This was dealt with at some length when we pointed out that it is not difficult to make an upset joint as strong as the body of the pipe. Only 85 per cent efficiency is claimed for the special upset joint they discuss, so that joint efficiency must have been sacrificed to gain clearance. Since the upset is on the inside, internal clearance has also been reduced. If this is permissible, the efficiency of any A.P.I. joint can be improved from 14 to 20 per cent. Take as an example the 7-in. O.D. size. The tentative A.P.I. long thread and coupling standard has an efficiency of 71 per cent for this size. It is understood that this special joint secures an increase in wall thickness of 0.052 in. by means of the internal upset. Based on the effective thickness, that is, the thickness at the root of the first full thread, this represents an increase of more than 14 per cent on the heaviest weight—more on the lighter weights. Add this to the 71 per cent and the joint efficiency is 85 per cent, which is the figure claimed for the type of joint presented by Mr. Eaton and Mr. Frame.

We have shown that the maximum clearance between strings, regardless of type of joint or thread employed, can be obtained by using a coupling of higher tensile properties than the pipe. It is obvious that a bell end formed as an integral part of the pipe made from grade C or grade D steel cannot be made as thin, without sacrificing strength, as can a coupling from steel of higher tensile properties.

We are unable to check the difficulty in running casing as pictured by Mr. Eaton, but however difficult it may appear, it must be admitted that there has been virtually no trouble in meeting these conditions with casing made to A.P.I. standards. The slight trouble that has occurred resulted from joints damaged in handling. A thin bell end made from relatively low-tensile material, and joints that depend upon an accurately machined water seal at the end of the thread, will probably be damaged much more easily than will A.P.I. standard joints.

Of the total time required for raising the casing, setting spider slips, attaching elevators, and screwing up, the latter operation represents a small portion. Thus, it is obvious that if this screwing up time were cut in half by doubling the taper, it would affect the total time very little. On one actual test of such special casing the average running time per joint was figured as 2.65 minutes, which could be compared with 3.15 minutes per joint required for a somewhat larger size of casing with A.P.I. type threads that was set with great care in Gulf's well, McElroy No. 103, and established the world's record for long strings.

Casing users are getting excellent performance from joints of the A.P.I. type, and we believe that all service conditions can be met without the necessity of going to rather complicated lathe-threaded designs.

Efficiency of Flowing Wells*

Summarized Results and Calculations of an Investigation in the Masjid-i-Sulaiman Field by the Anglo-Persian Oil Company, Limited

By Cecil J. May†

(Tulsa Meeting, October, 1934)

The importance of a knowledge of the physical laws involved in the production of oil from a reservoir has come to be generally realized in recent years and it is therefore unnecessary to elaborate on the many problems which still await complete solution. Among them the vertical flow of mixtures of oil and gas has attracted considerable attention and a number of papers have appeared in the literature from time to time. The complete solution of the problem would cover such aspects of oil-field technology as the calculation of bottom-hole pressures from purely surface data; the estimation of natural flowing lives; the design of gas-lifts and the selection of tubing for natural flow, and so on. It is still true, however, that the results so far published have not been particularly consistent and there are no generally accepted data available of universal applicability. It is, in fact, by no means easy to obtain a sufficiently wide range of variables under the operator's control to determine the laws of flow without ambiguity and much of the published research has been directed towards the solution of the specific problems of individual fields representing only a partial treatment of the whole subject. It was with a similar object that work was commenced on the Masjid-i-Sulaiman field of the Anglo-Persian Oil Co. towards the end of 1930 and has since continued as opportunity offered.

Of course, the results obtained cannot necessarily be applied elsewhere without modification and, in some cases, considerable extension. At the same time conditions in this field are somewhat unusual in allowing certain aspects of the problem to be isolated and examined without the disturbing effects of a large number of independent or partially independent variables. For example, since the field is under unit control, it is possible to maintain steady conditions on any particular well over long periods. Moreover, the structure of the limestone reservoir is such that the gas-oil ratio for a given well is sensibly constant over very wide ranges of production rates, and in many cases the bottom-hole differential pressure is negligibly small even at rates of flow of 10,000 to 20,000 bbl. or more per day. It is possible therefore to study experimentally, but on the full scale, flow in wells with a fluid of unvarying composition over the full range of pressures available in the field. Many of the experimental results, with a theoretical discussion, have already been published[1], but it is felt that a satisfactory solution of this simple form of the problem may be of value in correlating results obtained under more complicated conditions, and it is rather from this point of view that the present paper is written.

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GENERAL EQUATION OF FLOW

In the paper by May and Laird (footnote 1), the general equation of flow was given in the form:

$$144v\,dp = dx + \frac{vw^2dv}{gA^2} + \frac{144\left(v - \frac{1}{\rho}\right)dp}{v\frac{w}{Ab} + 1} + \frac{4kv^2w^2dx}{gDA^2}$$

where the various symbols have the following meanings:

dx, small increment in height in well, ft.

dp, corresponding small change in pressure, lb. per sq. in.

D, casing diameter, ft.

A, casing area, sq. ft.

w, weight of total fluid (i.e., oil + associated gas) passing through well per second, lb. per sec.

ρ, density of oil, lb. per cu. ft.

v, specific volume of total fluid at pressure under consideration, cu. ft. per lb.

b, velocity of slip between gas and oil, ft. per sec.

k, friction factor.

From its method of derivation (of which limits of space do not permit the republication) this formula should be applicable to all conditions of flow, its numerical computation requiring a knowledge of the physical properties of the fluid and of two more or less arbitrary factors.

EFFECTIVE PROPERTIES OF FLUID

Implied in this formula are the properties of the fluid which are effective in determining flow. The important properties of the oil itself are the density, viscosity and surface tension, all of which increase as the pressure falls in the well and gas comes out of solution[2,3]. Our results tend to show that this increase is unimportant as far as calculations on any one well are concerned, but it does not follow that oils of very different basic physical properties will behave in precisely the same way with regard, for example, to slippage.

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[1] May and Laird: *Jnl.* Inst. Petr. Tech. (1934) 214.

[2] D. T. Jones: *Proc.* World Petr. Congress (1934) **1**, 467.

[3] Lindsly: *Oil & Gas Jnl.* (Jan. 1, 1933).

The other important quantity is the gas-oil ratio. As ordinarily measured, this is a combination of two factors: the gas actually held in solution in the oil under reservoir pressure, which we may term dissolved gas, and free gas drawn into the well from the formation. In Masjid-i-Sulaiman we are fortunate in that we are rarely troubled with free gas and the problem therefore is very much simplified. Considering, for the moment, only dissolved gas, it has been pointed out that the value obtained for the gas-oil ratio depends upon the method adopted for its measurement[4,5]; on whether the gas is removed from solution in a single flash or in a number of stages. The discrepancy is due, of course, to the fact that we are not in general dealing with a pure gas dissolved in a nonvolatile liquid, but with one of variable composition including the vapors of low-boiling liquid hydrocarbons. The temperature of separation and the attainment of true equilibrium also require close attention if accurate and repeatable values are to be obtained, so that ordinary field measurements cannot be expected to provide more than a rough approximation. A considerable amount of work has been carried out in Persia on this subject from a number of different points of view. We require, for example, to calculate the optimum number of stages and pressures of gas separation to retain the maximum amount of volatile liquid hydrocarbons in the residual crude.

From the point of view of reservoir control and the flow of wells the saturation pressure has been found of considerable value as an easily measured and unique property of a given reservoir crude. If a sample of oil is drawn from the bottom of a well, maintained at reservoir temperature, and the pressure slowly released, the saturation pressure is defined as that pressure at which gas is first evolved from solution. The use of this quantity avoids any ambiguity and considerably simplifies interpolation, as will be seen from the curves and nomograms given herewith. The saturation pressure varies from one point in the reservoir to another in a manner that has been discussed by Comins and Pym[6,7] and to which space will not permit of further reference here. Once the law of distribution has been determined, however, it has been possible to consider very simply possible future variations.

The effect of free gas represents a difficult problem with which we have not had to deal. The obvious solution that suggests itself is that the

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[4] Reference of footnote 3.

[5] Comins: *Proc.* World Petr. Congress (1934) **1**, 458.

[6] Reference of footnote 5.

[7] Pym: *Proc.* World Petr. Congress (1934) **1**, 452.

pressure at which the oil produced will dissolve the whole of its associated gas should be employed as a nominal saturation pressure, and, for the purpose of discussion, this will be assumed in what follows.

Finally, it should be mentioned that in this work it is convenient to express gas-oil ratios in terms of the volume of gas associated with unit volume of oil rather than in some arbitrary unit such as cubic feet per barrel. Thus a 40.1 ratio is equivalent to 225 cu. ft. per barrel, or (for Persian crude) to a saturation pressure of about 460 lb. per sq. in. absolute.

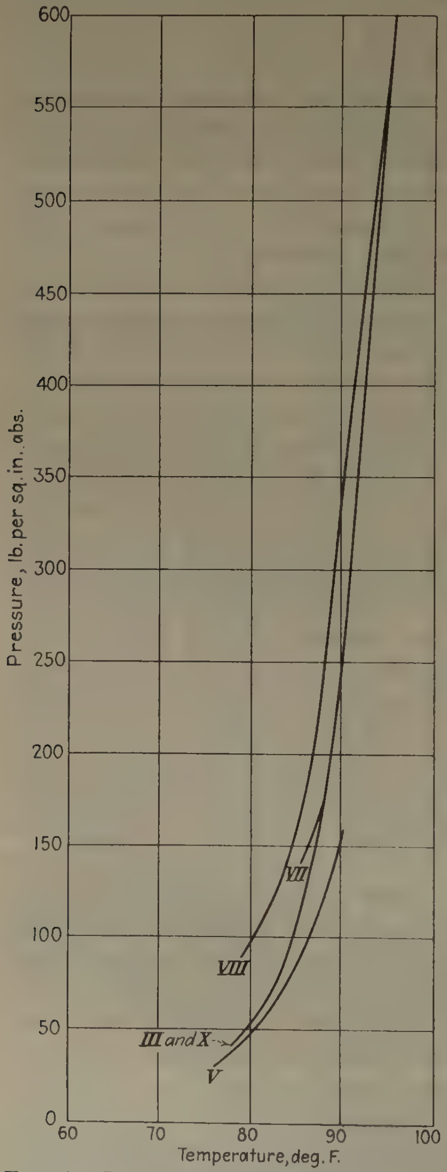

Fig. 1.—Pressure-temperature curves. Numbers refer to Table 1.

Available Energy

If one attempts to calculate the energy available from the expansion of this associated gas with falling pressure from first principles considerable complications arise due to deviations from the simple gas laws. The necessary corrections are quite simply covered by the experimental method used in the work at present under discussion. (See also example 3.) A sample of reservoir crude oil is drawn containing the whole of its dissolved gas under reservoir pressure[8,9] The sample is held in a closed container over mercury and a pressure volume curve for the total oil + gas is determined experimentally by measuring the fall in pressure as known amounts of mercury are removed from the apparatus. In an actual flowing well the temperature falls from the bottom upwards and is not a unique function of the pressure. However, we have found it

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[8] Reference of footnote 1.

[9] Reference of footnote 7.

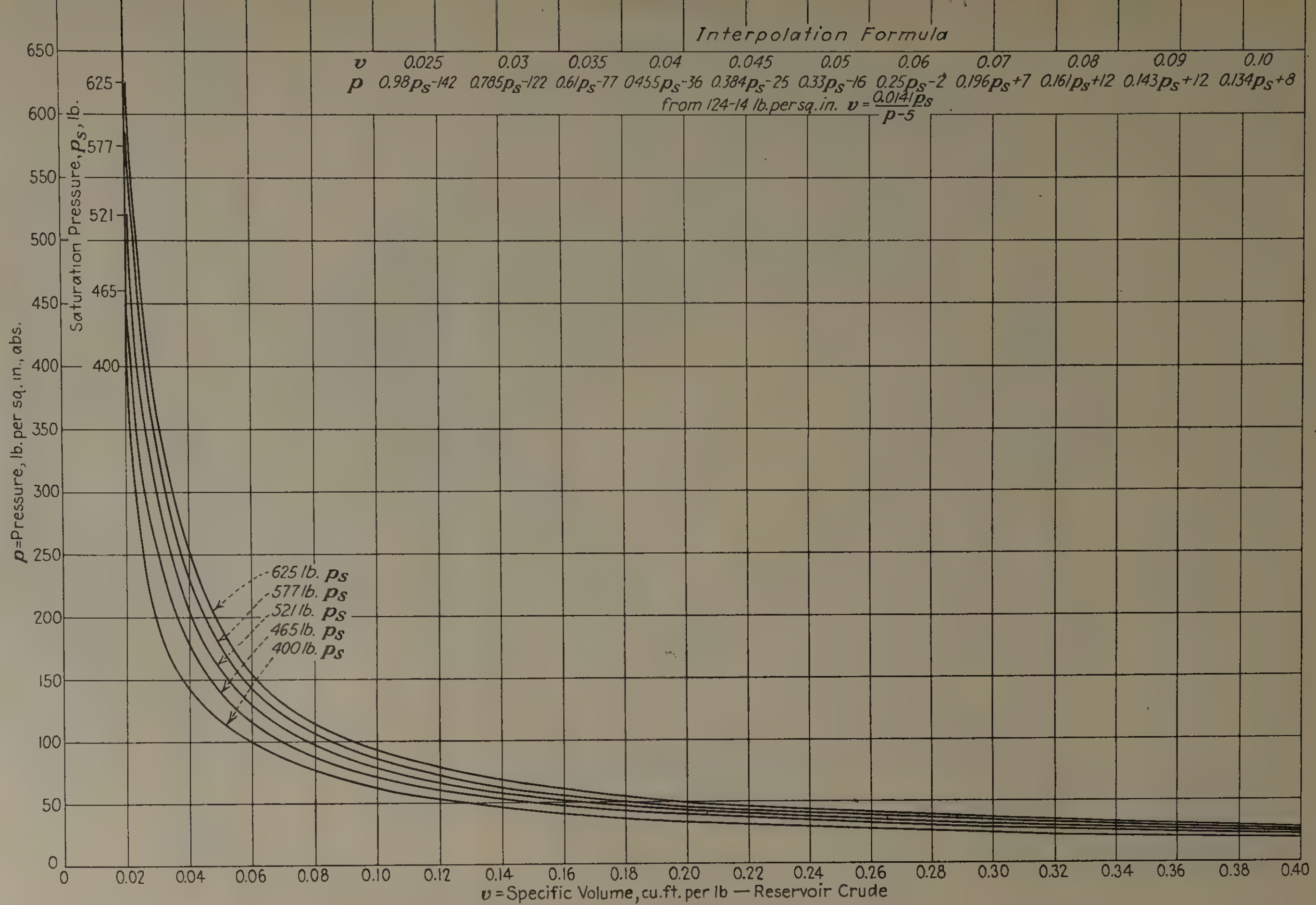

FIG. 2.—EXPERIMENTAL PRESSURE-SPECIFIC VOLUME CURVES, MASJID-I-SULAIMAN OIL, AT 465 AND 577 LB. PER SQUARE INCH ABSOLUTE.

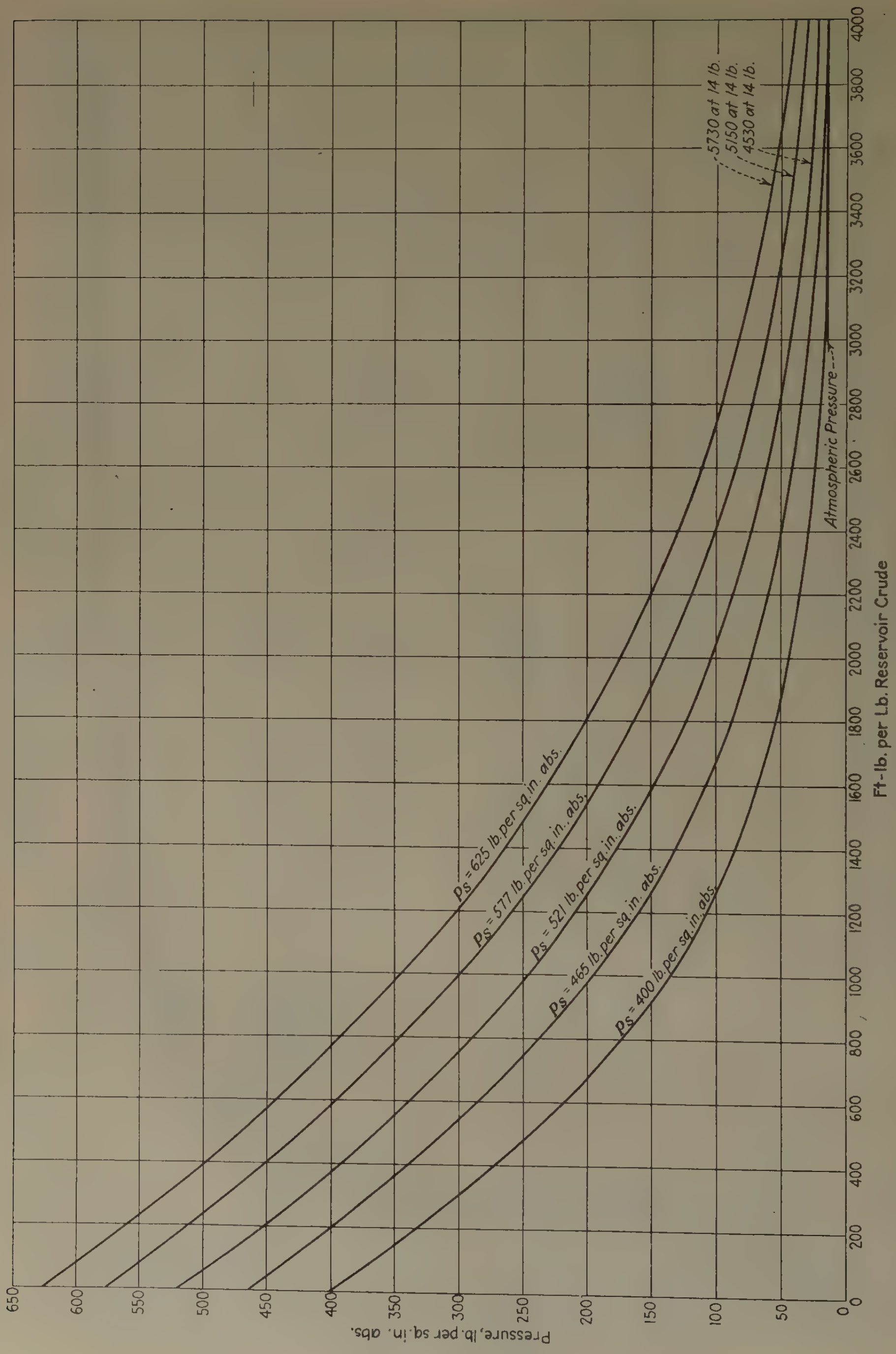

FIG. 3.—PRESSURE-ENERGY CURVES, MASJID-I-SULAIMAN OIL. AVAILABLE ENERGY BETWEEN SATURATION PRESSURE p_s AND ANY LOWER PRESSURE.

sufficiently accurate for most practical purposes to assume that it is and have determined a suitable average pressure-temperature curve for a well in Masjid-i-Sulaiman (Fig. 1). In measuring our pressure-volume curves the temperature is adjusted to correspond to this average p-T curve. p-v curves are measured for a few samples of oil with different

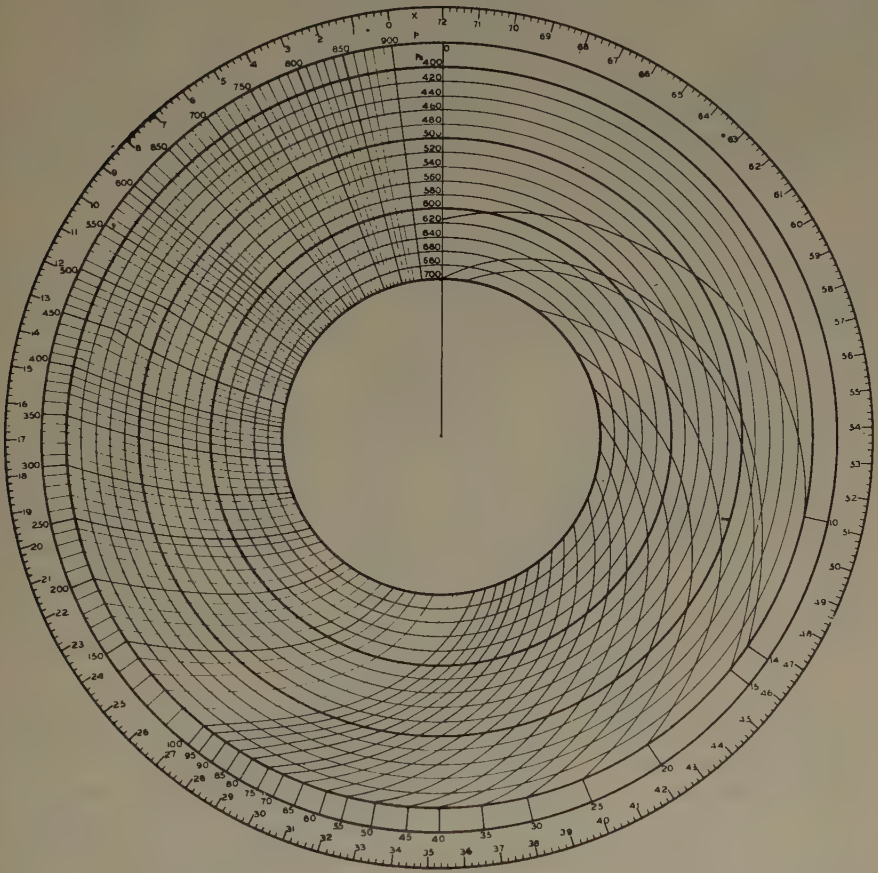

FIG. 4.—PRESSURE-AVAILABLE ENERGY NOMOGRAM.

saturation pressures and interpolation between them is then a simple matter. In Fig. 2 are shown a number of typical curves, v being expressed in the units cubic feet per pound of reservoir crude.

The energy available on expansion of a fluid is

$$144\int_{p_1}^{p_2} v\,dp \text{ ft-lb. per lb.}$$

where p_1 and p_2 are the stated pressure limits in pounds per square inch absolute. Simple graphical integration therefore gives Fig. 3, or the mere convenient nomographic form Fig. 4, where is plotted the energy

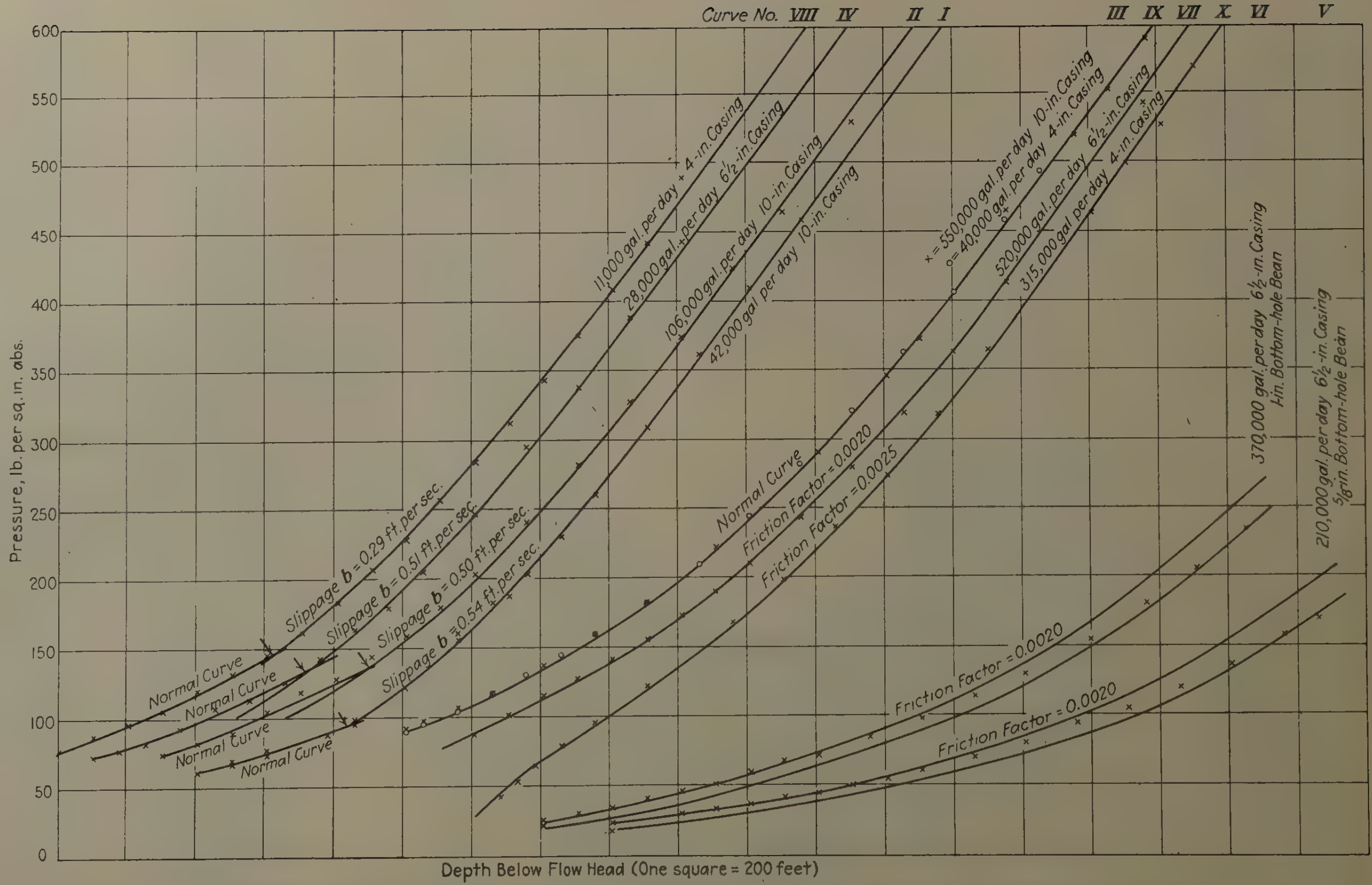

FIG. 5.—PRESSURE-DEPTH CURVES. x AND o EXPERIMENTAL POINTS CALCULATED. COMPARE WITH TABLE 1.

in foot-pounds per pound of reservoir crude between a given initial and any final pressure.

EXPERIMENTAL PRESSURE-DEPTH CURVES

With a view to checking the calculated general equation of flow and of evaluating the unknown quantities therein, a number of experiments were carried out on a particular well using various rates of flow and flow-string sizes. The experiments consisted in measuring the pressure at various depths in the flowing well and the experimental points are plotted in Fig. 5 for the more important tests, the essential details of which are given in Table 1. The general equation of flow given above was then used with suitable values of the constants to calculate the full lines drawn over the plotted points in the figure. As is normally expected, it was found that at high rates of flow friction was the major cause of loss of energy, and at low rates slippage was the major cause; but it was also found that the two were never simultaneously of appreciable magnitude and at intermediate rates of flow all such energy losses became negligible. Under these conditions the last three terms of the general equation of flow can be equated to zero and we obtain simply

TABLE 1.—*Details of Tests Plotted in Figure* 5.

Curve Number in Fig. 5	Flow String, In.	Production Rate		Velocity of Gas-free Oil, Ft. per Sec.	Flow-head Pressure, Lb. per Sq. In. Abs.	Actual Gas-oil Ratio at Flow Head	Mean Velocity at Flow Head, Ft. per Sec.
		Gal. per Day	Bbl. per Day				
I	10	42,000	1,200	0.16	61	5 :1	0.96
II	10	106,000	3,030	0.39	74	4 :1	1.9
III	10	554,000	15,800	2.12	91	2.5:1	7.4
IV	6½	28,000	800	0.26	72	4 :1	1.4
V[a]	6½	210,000	6,000	1.99	18–24	25 :1	52.0
VI[a]	6½	370,000	10,600	3.5	19–22	22 :1	80.0
VII	6½	520,000	14,850	4.94	82	3 :1	20.0
VIII	4	11,000	314	0.27	76–77	4 :1	1.4
IX	4	42,000	1,200	0.99	89.5	2.5:1	3.5
X	4	315,000	9,000	7.8	21	8 :1	74.0

[a] Flowing through bottom-hole bean.

$$144\int v\,dp = \int dx$$

or, in other words, the curves of Fig. 3 are actual pressure-depth curves. This is demonstrated by curves III and IX of Fig. 5, in which the full line is transferred direct from Fig. 3 and shows excellent agreement with the two sets of experimental results. At lower rates of flow it is necessary to consider only the effect of slippage in reducing the efficiency of flow.

SLIPPAGE

The energy loss known as slippage is due to the tendency of gas to rise in the well faster than the oil. Its calculation is somewhat complicated and considerations of space forbid its being reproduced here. The formula derived in a previous paper is

$$144v\,dp = dx + \frac{144\left(v - \frac{1}{\rho}\right)}{v\frac{w}{Ab} + 1}dp$$

the important feature of which is the velocity of slip b. According to Versluys[10], there are two fundamentally different types of flow. In the first there is relatively more oil present than gas and individual gas bubbles rise through a continuous oil phase ($b = 0.6 - 1$ ft. per sec.). As the ratio of gas to oil actually present at the pressure obtained in the well approaches 1:1, slippage decreases to a negligible quantity and then increases again as gas becomes the continuous phase and oil droplets fall through it ($b = 30$ ft. per sec.). These he defines as the foam and the mist conditions. Our results are in general agreement with this conception so far as the so-called foam condition is concerned. Putting $b =$ approx. 0.5 in the above formula, the agreement shown in curves I, II, IV and VIII is obtained. The mist condition does not, however, occur as soon as the 1:1 gas-oil ratio is reached. On the contrary, a stable foam appears to be formed (as shown by the sharp break in each of these curves) in which the slippage loss is negligible and which persists up to gas-oil ratios of at least 5:1 and probably 10:1. At still higher expansion ratios surging sets in, due to the movement of alternate plugs of gas and foam up the casing (curves V and VI) but we have not succeeded under the conditions obtaining in Persia in determining the point at which true mist flow commences. The oil films in the stable foam are obviously approximately flat and not spherical, as is assumed as the basis of Versluys' argument.

Even in fields in which mist flow is important our method of correcting for the energy loss due to slippage in the lower part of the well should still prove of value. From the above formula it is evident that the slippage is completely determined by the p-v curve and the quantity $\frac{w}{Ab}$; i.e.:

$$\frac{\text{weight of reservoir crude in lb. per sec.}}{\text{area of casing in sq. ft.} \times \text{velocity of slip in ft. per sec.}}$$

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[10] Versluys: *Trans.* A.I.M.E. (1930) **86,** 192; *ibid.* (1931) **92,** 279; *Jnl.* Inst. Petr. Tech. (1933) **19,** 694.

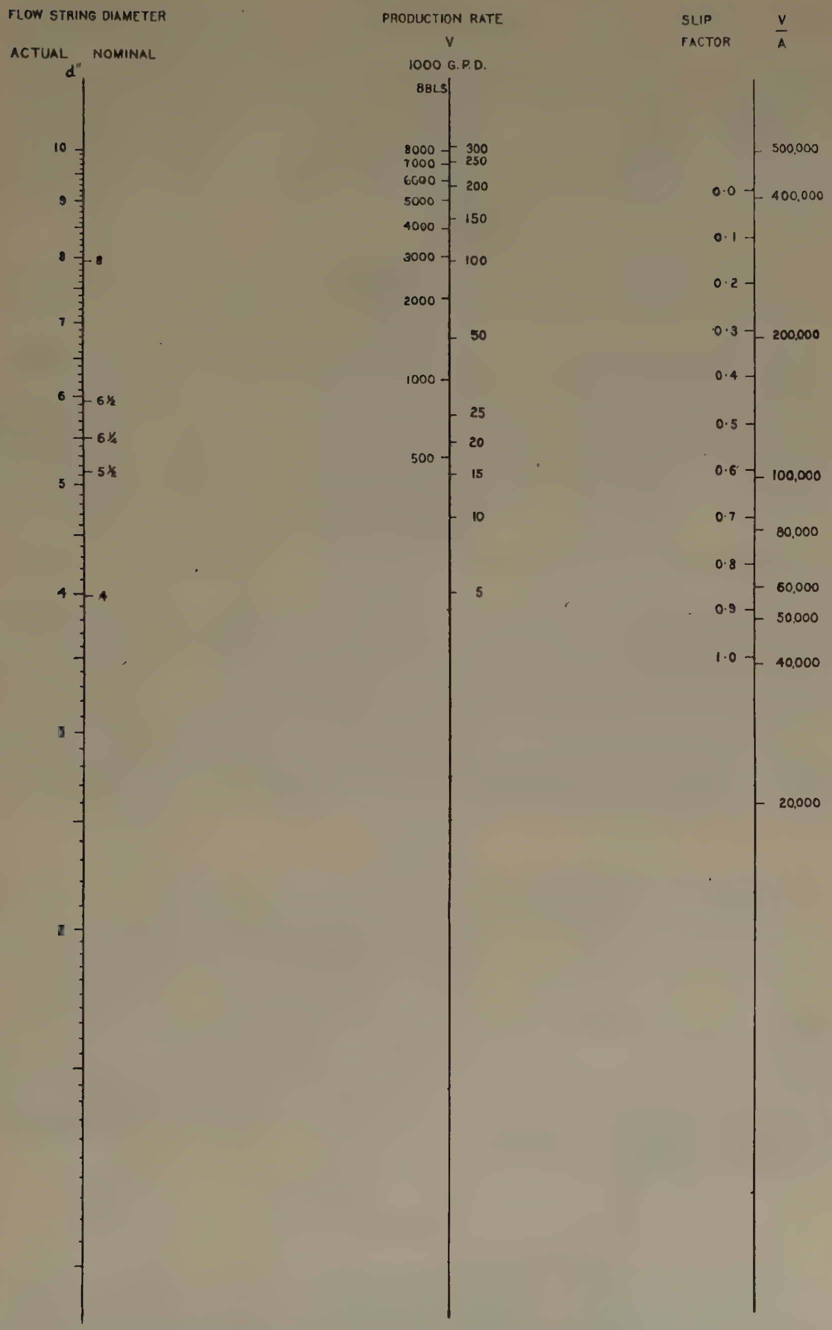

Fig. 6.—Slippage correction. Multiply slip factor by saturation pressure.

It appears that if $\frac{w}{Ab}$ is greater than 100, the total energy loss due to slippage in the foam condition amounts to not more than a few foot-pounds per pound of oil, and this, therefore, provides a convenient limit in the design of suitable flow strings. Thus, for example, a 4-in. string has a cross-sectional area of 0.087 sq. ft.; taking $b = 0.5$ for M.i.S. oil, we have for the limiting case

$$\frac{w}{0.087 \times 0.5} = 100 \text{ or } w = 4.35 \text{ lb. per sec.}$$
$$= \text{approx. } 1250 \text{ bbl. per day.}$$

At any rate greater than 1250 bbl. per day through a 4-in. flow string, therefore, slippage can be entirely neglected, with our particular oil. A further simplification arises from the fact that foam slippage ceases abruptly at a point in the well that usually is some distance from the surface. In order to calculate the pressure drop over the whole well, therefore we only require to know the *total* slippage loss, which is a function only of the saturation pressure and $\frac{w}{A}$ (b being assumed constant). A nomogram (Fig. 6) shows this relationship; the slippage correction read from the diagram is simply added to the depth of the well and Fig. 4 is then used to calculate the pressure drop. (See example 2.) It should again be mentioned that we have no information whatever on the subject of mist slippage, which so far has not entered into any of our practical calculations; and some doubt may also be expressed as to the validity of extrapolating our results to cover very small flow strings.

FRICTION

According to the ordinary theory of fluid flow, the energy loss due to friction is proportional to the velocity and to the viscosity of the fluid at low values of the Reynold's criterion $\left(\frac{uD\rho}{\eta}\right)$ and to the square of the velocity and independent of the viscosity at high values. It is by no means easy to ascribe a rational value to the viscosity of a heterogeneous mixture of gas and oil, and in the only detailed experimental work previously published on the subject a purely empirical eq.ⁿ is used for the calculation of friction loss[11,12]

$$\Delta P_{fr} = 0.00125 \frac{u\rho Z^{0.18}}{d}$$

where ΔP_{fr} is the friction loss, u the velocity, ρ the density and Z the viscosity of the oil phase. There seems to be no theoretical justification

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[11] Moore and Schilthuis: *Trans.* A.I.M.E. (1933) **103**, 170.

[12] Reistle and Hayes: U.S. Bur. Mines *R. I.* 3211 (1933).

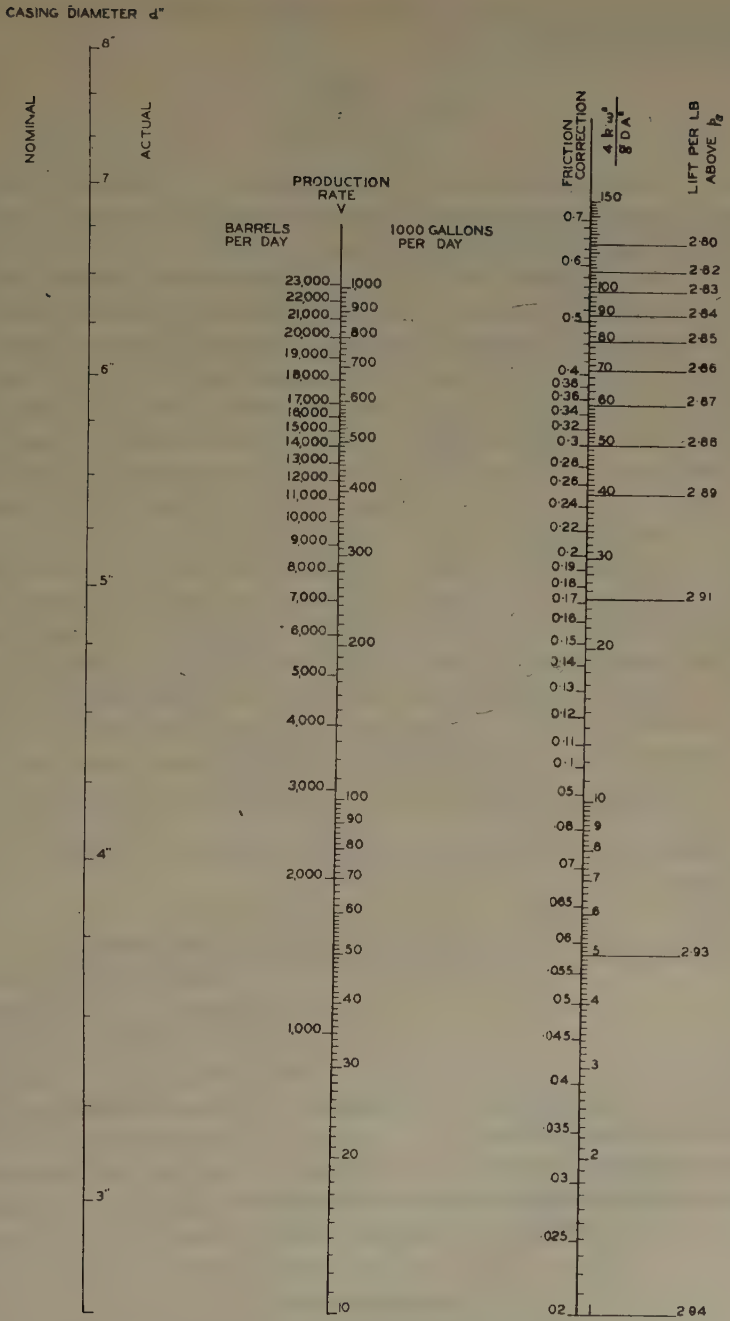

FIG. 7.—FRICTION CORRECTION.

Above saturation pressure, use figures in last column.

Between saturation pressure and pressure $0.161\ p_s + 12$ use friction correction multiplied by saturation pressure.

Below pressure $0.161\ p_s + 12$ use standard formula.

for such a formula and we in fact find that at high rates of flow the ordinary formula holds:

$$dW_4 = \frac{4kv^2w^2}{gDA^2}dx$$

where k is a constant independent of the velocity. (It should be observed that the value of k depends upon the relative roughness of the pipe and is slightly different for different diameters.)

If the two formulas given above are compared they will be found to give approximately the same numerical result at a velocity of 1 ft. per sec. It is necessary to go to a velocity of some 4 ft. per sec. before the friction loss on our formula amounts to as much as 1 per cent of the total energy; therefore we feel that, although derived from experiments at high velocities, the formula can be used for all practical purposes over the whole range. Curves VII and X, Fig. 5, were calculated on this basis with added correction for velocity head; in curves V and VI the apparent spread is due to surging.

For the purposes of calculation, it will be evident that the calculated flowing pressure of a well will be greater if we neglect friction than if friction is included. It would be possible to plot the difference between these two pressures for various conditions of flow in the form of a nomogram. This would however be somewhat complicated and a simpler form is shown on Fig. 7. Advantage is taken of the fact that below about 120 lb. per sq. in. the p-v curves are very nearly true hyperbolas and are represented by the formula $v = \frac{0.0141p_s}{p - 5}$ for M.i.S. oil. Over this range it is therefore possible to integrate the general eq.ⁿ of flow to give

$$X = 72 \times 0.0141p_s \times 2.3\left[\log_{10}\left\{(p-5)^2 + \frac{0.0141^2p_s{}^24kw^2}{gDA^2}\right\}\right]_{p_2}^{p_1} - \frac{2.3D}{8k}\left[\log_{10}\left(v^2 + \frac{gDA^2}{4kw^2}\right)\right]_{v_1}^{v_2}$$

where X is the depth of the well and the last term is the velocity-head correction discussed below.

A nomogram is therefore constructed to cover the friction correction at high pressures and the formula is used at low pressures. An example of the method of calculation is given below (example II).

VELOCITY HEAD

At very high rates of flow it is necessary to apply a correction for velocity head which follows normal theory. We have

$$\int dW_2 = \frac{u^2}{2g} = \frac{v^2w^2}{2gA^2}$$

whence

$$dW_2 = \frac{vw^2}{gA^2}dv$$

(The application to the calculation of the maximum throughput of a bean on the lines of the ordinary steam-jet theory has been discussed in a previous paper but is too long to be included here.)

It is only rarely necessary to apply this correction, since it is barely measurable even with a velocity at the flow head of 20 ft. per sec. At such rates slippage is absolutely negligible and the eq.^{n} of flow becomes

$$dE = 144vdp = dx + \frac{vw^2dv}{gA^2} + \frac{4kv^2w^2dx}{gDA^2}$$

or

$$\int dx = \int \frac{144vdp}{1 + \frac{4kv^2w^2}{gDA^2}} - \int \frac{vw^2dv}{gA^2\left(1 + \frac{4kv^2w^2}{gDA^2}\right)}.$$

The last term on the right-hand side is the velocity-head correction and in integration yields:

$$-\frac{2.3D}{8k}\left[\log_{10}\left(v^2 + \frac{gDA^2}{4kw^2}\right)\right]_{v_1}^{v_2}$$

See example 2.

Practical Applications

A few examples illustrating the use of the methods and nomograms described are appended. They represent actual experimental data obtained on the field.

Example 1.—Well A. Depth, 3088 ft.; casing, 10 in.; production rate, 2380 bbl. per day; flowing pressure, 49.5 lb. per sq. in. abs.; sat.^{n} press., 524 lb. per sq. in. abs. To calculate the bottom-hole pressure.

The production rate is so low that there is no appreciable friction. On the slippage-correction nomogram (Fig. 6) take a line through 10 in. on the left-hand scale and 2380 bbl. per day on the middle scale. On the right-hand scale read a slip factor of 0.42. Multiply by the saturation pressure to give the slippage correction: $0.42 \times 524 = 220$. Total energy required in well is therefore $3088 + 220 = 3308$ ft.-lb. per lb. Turn to the nomogram, Fig. 4. Take the point where the curve $p = 49.5$ cuts the circle $p_s = 524$ and join to the center; extend the line and read 3950 on the outer circle. This corresponds with the flow head; ∴ join the center to the point $3950 - 3308 = 642$. On the circle $p_s = 524$ read the pressure $p = 680$ lb. per sq. in. abs. (actually measured pressure = 684 lb.).

Example 2.—Well B. Depth, 2100 ft.; casing, 4 in.; production rate, 9000 bbl. per day; flowing pressure, 41.5 lb. per sq. in. abs.; sat. press., 465 lb. per sq. in. abs. To calculate the bottom-hole pressure.

This example is rather more complicated. There is no slippage but considerable friction and velocity head (it represents, in fact, curve X, Fig. 5). To begin with the nomogram, Fig. 7 gives the friction correction down to a pressure of $0.161p_s + 12$; in this case $0.161 \times 465 + 12 = 87$ lb. per sq. in. abs. Between this pressure and the flowing pressure of 41.5 lb. we use the formula:

$$X = 72 \times 0.141p_s \times 2.3 \left[\log_{10}\left\{ (p - 5)^2 + \frac{0.0141^2 p_s{}^2 4kw^2}{gDA^2} \right\} \right]_{p_2}^{p_1} - \frac{2.3D}{8k}\left[\log_{10}\left(v^2 + \frac{gDA^2}{4kw^2} \right) \right]_{v_1}^{v_2}$$

The value of $\frac{4kw^2}{gDA^2}$ read from the nomogram is 132 and k for 4-in. pipe is 0.0025. The formula therefore reduces to:

$$X = 72 \times 0.0141 \times 465 \times 2.3 \log_{10}\left\{ \frac{(87 - 5)^2 + 0.0141^2 \times 465^2 \times 132}{(41.5 - 5)^2 + 0.0141^2 \times 465^2 \times 132} \right\} - \frac{2.3 \times 0.33}{8 \times 0.0025} \log_{10}\left\{ \frac{0.186^2 + 1/132}{0.08^2 + 1/132} \right\}$$

The value of v corresponding to the flowing pressure ($v = 0.186$) is read from Fig. 2.

The arithmetical solution of this equation is $x = 250$; i.e., the pressure is 87 lb., 250 ft. below the 41.5-lb. pressure point (this can be checked on the curve x, Fig. 5). Between this pressure and saturation pressure, if there were no friction, the corresponding depth in the well would be 1800 ft. from the curve of Fig. 3.

From Fig. 7 the friction correction is 0.68 (scale reading corresponding to $\frac{4kw^2}{A^2gD} = 132$). 0.68×465 (saturation pressure) = 316 ft. Between 87 lb. and 465 lb. per sq. in. abs., the corresponding depth in the well is, therefore, $1800 - 316 = 1484$ ft.

Above saturation pressure there remains therefore $2100 - 1484 - 250 = 366$ feet.

Again, from the last column of Fig. 7, the lift per pound pressure drop at this particular rate of flow is 2.79 ft. per lb. Therefore 366 ft. corresponds to 131 lb. per sq. in. and the bottom-hole pressure is $465 + 131 = 596$ lb. per sq. in. abs. (actual observed pressure, 600 lb. per sq. in.).

Example 3.—Well C. Depth, 2118 ft.; casing 10 in.; production rate, 12,000 bbl. per day; flowing pressure, 90 lb. per sq. in.; bottom-hole pressure, 546 lb. per sq. in. To calculate the saturation pressure.

The nomograms, Figs. 6 and 7, show that both friction and slippage are negligible. On Fig. 4 take a vertical line passing through $p = 546$ (the variation with saturation pressure in this region is small). Read off 1020 ft. in the outer circle. Add the depth of the well and obtain 3138. Take a line from the center to 3138 and where it cuts the $p = 90$-lb. line read off the saturation pressure 495 lb. per sq. in. absolute.

Many variations of these methods are possible and suggest themselves in the course of ordinary field work. They have been applied in Masjid-i-Sulaiman to the calculation of pressure drops over a very wide range of conditions, and, provided that flow is steady, the maximum divergence from the experimental figure has been equivalent to about 2.5 per cent of the total energy used in the well; in the great majority of cases the error is less than 1 per cent.

Considerations of space have made it impossible to do more than give a very brief outline of the subject in the present paper, but it is hoped that it will serve the purpose of stimulating discussion on an extremely important topic.

ACKNOWLEDGMENT

The author's thanks are due to the Chairman and Directors of the Anglo-Persian Oil Co. for permission to publish the results of this investigation.

Some Economic Aspects of Gas-solubility Investigations

By Alexander B. Morris*

(Tulsa Meeting, October, 1934)

Studies such as the investigations into the solubility of gases in crude oil under various conditions, which have been carried on during the past three or four years, are very interesting from an academic point of view, but this consideration alone is hardly sufficient to warrant the large contributions from the industry necessary to maintain them. Some definite benefit to the industry as a whole should be forthcoming. The purpose of this paper is to direct the attention of company engineers, and company executives, to some of the ways in which the information gained from these studies can be made directly profitable.

This work has two principal economic aspects. One affects the investment budget, and through it the financial requirements of the companies. The other affects operations, and through this course is reflected in current earnings. It will be shown that, as a direct result of the investigations into gas solubility, undertaken in the recent past by various investigators, it is now possible:

1. To determine more accurately the amount of reservoir oil originally present.
2. To obtain closer control on operating conditions, to effect more economical recovery.
3. To predict earlier and more dependably when and how much surface lifting equipment will be needed.
4. To reduce, or entirely avoid the very large investment in gasoline recovery equipment now frequently found necessary.
5. To control the gravity of the pipe-line oil so as to secure the greatest possible revenue from the products of the well.
6. To effect the recovery of a large amount of gasoline now wasted while the practicability of a gasoline recovery system is being decided.
7. To plan operations, by comparison with the history of old properties operated without this new information, so as to avoid the mistakes of ignorance made in the past.

These points will be discussed in the following pages, though not necessarily in the order stated. There is so much overlapping of the points themselves, and of the data from which they have been drawn as conclusions, that to treat them in any particular order would require

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tiresome repetition of many of the facts presented. It was more practical to present the data in as concise a form as possible, pointing out during its discussion its application to the primary purpose of this paper.

During the past three or four years much time and labor have been expended[1]* in efforts to determine the solubility of natural gas in crude oil, under various conditions of pressure and temperature. The early attempts resulted in conclusions that apparently were considerably at variance, and it was not until Lindsly's work[2] with Oklahoma City and several California crude oils that definitely consistent results were attained. Lindsly pointed out that the apparent differences between the findings of these earlier investigators resulted from a failure on their part to duplicate natural conditions by choosing as working media gases containing no condensible components and oils containing none of the lighter fractions, including permanent gases.

By securing well-head and bottom-hole samples of oil with the gas actually in solution at the pressures prevailing at the sampling points, working media were obtained which contained all components, from the lightest to the heaviest, in their natural proportions. By liberating this dissolved gas in pressure steps, and analyzing each cut liberated, it was possible to construct curves for each of the crude stocks chosen, which showed the amounts of the "gas" components remaining in solution at each pressure. Lindsly's results, at the same time that they provide much new material for study, reconcile the varying conclusions of the other investigators in this field by pointing out the reasons for their differences.

The practice of taking bottom-hole samples early in the life of a well, and periodically thereafter, provides information as early as the second sampling, for determining with a degree of reliability never heretofore even approached, the total amount of oil originally present in the reservoir. It provides numerical values for several of the constants in Coleman's formula[3]. The study of cores has had its emphasis changed. The role of porosity as a measure of reservoir space appears to be less significant than permeability. Pressure studies of the gas released from solution by differential liberation[4] show the amount of natural energy available for recovering the oil; and analyses of the several cuts show the composition of the gas that may be expected to be present in the gas cap at any lower pressure.

With this information it is now possible to appraise a pool within a few months of its opening, determining not only the quantity of oil in the reservoir but obtaining at the same time a guide to development and production programs. The validity of these results is impaired by the presence of water drive as a source of energy; so that where this condition exists its effect must be compensated for in the calculations. Unfortunately, complete information on the extent of water drive is never available until too late in the life of a field to be of any particular value. Where, however, there is no evidence of water drive, Coleman's formula and the values of the constants furnished by bottom-hole sampling yield very satisfactory results. The approximate date upon which wells will cease natural flow can be closely set for any given production rate, and the production rate resulting in the most economical recovery can be determined. The amount and kind of lifting equipment can be closely estimated long before it is needed, thus avoiding large emergency expenditures to keep the wells on production.

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* References are at the end of the paper,

The study of the analyses of the gas released from solution at various pressures below initial reservoir pressure will also reveal when and to what extent a gasoline plant in the field would be practicable. Lindsly's work at Oklahoma City and at Crescent, Okla.[5], furnishes data, further discussed below, which indicate that with proper facilities for receiving the oil from the well, a large part or even all of the gasoline-plant equipment now generally considered necessary can be avoided.

The ability to make such determinations early in the life of a field is of great value to the executives responsible for providing funds for development and operation. If a sale of an interest in a property is contemplated, estimates of value can be made which are free from many of the elements of uncertainty that now detract from the reliability of such calculations, especially where heavily prorated wells are involved. Where bottom-hole sampling has been conducted, the full results of these tests should be demanded by the prospective purchaser, before his engineers make a recommendation of value. With such data available, a higher price can with safety be paid for prorated new production than would be justifiable in their absence.

It is not necessary here to make a computation from Coleman's formula to show how the estimate of the original oil is prepared. The equation is complicated and the definitions of the quantities are necessarily long. The formula has been adequately illustrated by several numerical examples in the original presentation[3]. Instead, let us consider how bottom-hole sampling coupled with the gas-solubility data thus obtained may be used to govern operations and to predict investment requirements. Table 1 reproduces a part of Table 3 from Lindsly's report[5] on a bottom-hole sample taken at Crescent, Okla. This sample was taken at an original pressure of 2575 lb. per sq. in. absolute, and the original reservoir pressure was computed to have been 2829 lb. per sq. in. abs. Let it be assumed that this sample actually had been taken upon completion of the well, and that the computed initial reservoir pressure had been the pressure actually observed. Let it be further assumed that some months after this initial sampling another sample was taken, at which time the observed bottom-hole pressure had dropped to 2575 lb. per sq. in. abs. We would expect to find that the gas-solubility data derived from this second sample would closely check with line 2 of Table 1. If they failed to check within reasonable limits, it would indicate that the liberation of gas from solution in reservoir oil does not approximate differential liberation, as has been stated by Lindsly. Assuming that a check was obtained, the probability that a third test, taken at, say, 2144 lb. per sq. in. abs. would agree with line 3 of Table 1, obtained from the first sample, would be tremendously increased. A third test at 2144 lb. per sq. in. abs. would then provide enough points for plotting a "bottom-hole pressure decline curve," using bottom-hole pressure against time and against total withdrawals to date. Extrapolation of these curves would indicate what reservoir pressure might be expected at any date in the future at the present production rate, or after the withdrawal of any stated amount of oil.

Table 1.—*Solubility of Gas and Estimate of Solubility Based on Complete Saturation of Reservoir Oil, at* 149° *F.*

(Portion of Table 3, from Lindsly's Report of Experiments on Bottom-hole Sample at Crescent, Okla.)

Pressure, Lb. per Sq. In. Abs.	Total Gas, Cu. Ft. per Bbl. Residual Oil		Estimate Based on Complete Saturation at 2829 Lb. per Sq. In. Abs.			
			Cu. Ft. per Bbl. Initial Oil		Cu. Ft. per Bbl. Residual Oil	
	In Solution	Liberated	In Solution	Liberated	In Solution	Liberated
2829			642.10	00.00	877.0	00.00
2575	814.03	00.00	589.53	52.17	814.03	72.97
2144	678.99	135.04	492.06	150.04	678.99	208.01
1666	551.87	262.16	399.94	242.16	551.87	335.13
1223	442.95	371.08	321.01	321.09	442.95	444.05
813	319.60	494.43	231.61	410.49	319.60	567.40
354	184.44	629.59	133.37	508.73	184.44	702.56
101	102.62	711.41	74.37	567.73	102.62	784.38
14	00.00	814.03	0.00	642.10	00.00	887.00

Reference to the analyses of the several samples will indicate the amount and composition of the gas remaining in solution at each pressure interval, the available energy of the solution gas, and the composition of the gas in the gas cap. Adequate data are thus available for controlling the rate of production to effect the most economical recovery, and for forecasting the amount and kind of gas-lift or pumping equipment best suited to the needs of the case, and when it will be needed.

No proper operating program would now contemplate tapping the gas in the gas cap, so that a knowledge of the composition of this gas corresponding to various pressures is of no help in determining the practicability of a gasoline plant at some future date. Unfortunately, the experiments that have been made thus far do not show the composition of the gas released by flash liberation[4], between pressure P_m and P_n after the pressure on the oil has been reduced from the original reservoir pressure to P_m, the gas in this range having been liberated differentially. However, there are records[2] of two samples of gas from a well at Oklahoma City, one taken from the high-pressure separator and the other from the low-pressure separator. The conditions of liberation are as shown in Table 2.

TABLE 2.—*Conditions of Liberation*

To Which Was Subjected the Oil from Which Escaped the Gas Taken

Pressure Range	From High-pressure Separator	From Low-pressure Separator
From initial reservoir pressure to bottom-hole pressure	Mixed[a]	Mixed[a]
From bottom-hole pressure to well-head pressure, 1103 lb. per sq. in. abs.	Flash	Flash
From 1103 to 265 lb. per sq. in. abs.	Mixed	Mixed
From 265 to 16 lb. per sq. in. abs.		Differential

[a] Large amount of free reservoir gas present, introducing elements of flash liberation.

The well-head pressure was 1103 lb. per sq. in. abs., and a pressure of 265 lb. per sq. in. abs. was held on the high-pressure separator. The oil from this separator discharged into the low-pressure separator, on which a pressure of 16 lb. per sq. in. abs. was held. Initial reservoir and bottom-hole pressures are not shown, but the latter was probably greater than 2000 lb. per sq. in. Examination of the analyses of these gases reveals that the gas from the high-pressure separator contained substantial amounts of propanes and butanes, but that no pentane or heavier component is shown. The gas from the low-pressure separator contained much less methane and ethane, more butane, and substantial amounts of pentane. No fractions heavier than pentane are shown in the published data, but an adjustment has been made for this apparent inaccuracy, as hereafter described.

For the purpose of investigating the bearing of these experiments upon gasoline-plant installation, I have reconstructed from the analyses of the several gases liberated from solution under different pressure conditions, the types of commercial natural gasoline that could be extracted from each, assuming that all components of the gas heavier than iso-butane were completely recovered, and no components lighter than normal butane were recovered. These are shown in Table 3, and the gases from the two separators discussed above are shown on lines 8 and 9. In reconstructing these gasolines it has been assumed that the heaviest component shown in the gas analysis contained also all heavier components up to nonane, in proportion to their vapor pressures at 30° C.; and that the butane component was composed of iso-butane and normal butane in the proportion of 1:2. Only normal paraffin hydrocarbons were assumed to be present.

Line 8 of Table 3 shows the probable characteristics of the gasoline extractable from the gas from the low-pressure separator at this Oklahoma City well, assuming that all the N-butane present in the gas was condensed. This is not a commercial product, but by reducing the N-butane content to 25 per cent by weight, a product having the probable character-

TABLE 3.—*Comparison of Computed Properties of Iso-butane-free Natural Gasolines, Which Might be Extracted from Gases Liberated from Solution under Various Pressure Conditions*

	Gal. per Day	M. Cu. Ft. per Day	Gal. per M. Cu. Ft.	Gravity, Deg. A.P.I.	Approx. Vapor Pressure at 100° F., Lb. per Sq. In. Abs.	Percentage by Liquid Volume			Percentage Distilled Off	
						N-Butane	Pentane	Hexane and Heavier	At 100° F.	At 140° F.
Crescent Well, 42.1° A.P.I. Oil										
Separator gas:										
1. Using all N-butane in gas.....	1,672	466	3.58	98.2	32.54	47.2	31.7	21.1	72	87
2. N-butane reduced to 25 per cent wt......................	834	466	1.79	93.1	24.75	27.0	43.8	29.2	51	82
Gas from bottom-hole sample liberated above 101 lb. per sq. in. abs:										
3. Using all N-butane in gas.....	277	342	0.81	107.9	44.13	90.9	7.2	1.9	Cannot estimate	
4. N-butane reduced to 25 per cent wt......................	9	342	0.026	95.2	18.96	26.9	57.0	16.1	Cannot estimate	
5. Another gasoline............	17	342	0.049	100.4	24.93	51.5	37.3	11.2	Cannot estimate	
Gas from bottom-hole sample liberated between 101 and 14 lb. per sq. in. abs:										
6. Using all N-butane in gas.....	411	50	8.21	98.6	33.30	48.4	33.5	18.1	77	91
7. N-butane reduced to 25 per cent wt......................	196	50	3.91	94.1	24.30	26.8	47.3	25.9	57	87
Well "D" Oklahoma City 43° A.P.I. Oil										
Low-pressure separator gas, 16 lb. per sq. in. abs.:										
8. Using all N-butane in gas.....			2.31	99.3	36.18	56.2	23.2	20.6	Cannot estimate	
9. N-butane reduced to 25 per cent wt......................			0.78	93.1	23.72	26.9	38.8	34.1	46	74
Gas from well-head sample, differential liberation 283 to 15 lb. per sq. in. abs:										
10. Using all N-butane in gas.....			2.44	102.3	38.38	60.7	27.5	11.8	Cannot estimate	
11. N-butane reduced to 25 per cent wt......................			0.65	94.9	24.60	26.8	51.5	21.7	64	92
12. High-pressure separator gas, 265 lb. per sq. in. abs.........	[a]					Contains only traces of pentane and heavier				

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[a] Very high gas-oil ratio, possibly as high as 10,000 cu. ft. per barrel, due to presence of much excess free reservoir (?) gas.

istics shown in Table 3, line 9, is obtained. An approximation of the Engler distillation curve of such a gasoline is shown in Fig. 1, curve 4. This distillation curve and others prepared from similar analysis data have been constructed by reference to Pocock and Blair's[6] analysis chart for natural gasoline.

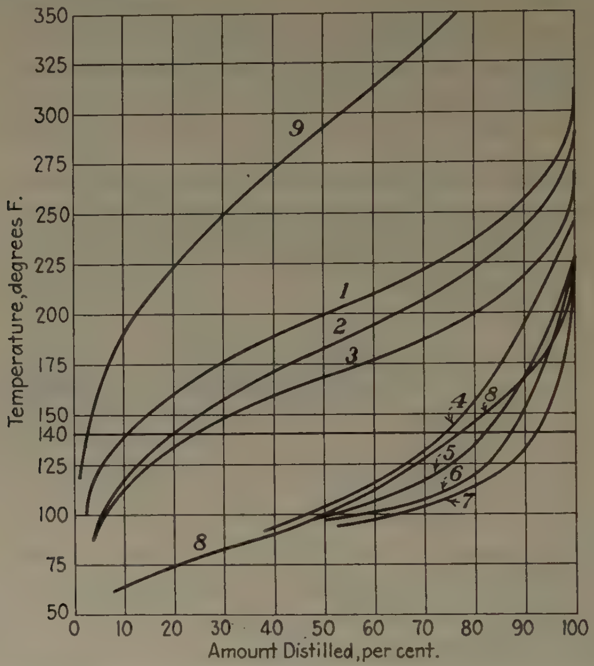

FIG. 1.—ENGLER DISTILLATION CURVES, CORRECTED FOR LOSS AT LOWER END.

CURVE	TABLE	LINE
1. Actual run of drip gasoline from Glenn pool, taken from drip 300 ft. from vacuum station.	5	4
2. Actual run of drip gasoline from Glenn pool, taken from drip 1500 ft. from vacuum station.	5	6
3. Actual run of drip gasoline from Glenn pool, taken from drip 1200 ft. further from vacuum station, on same line as yielded curve 1.	5	5
4. Constructed from analysis, gasoline from low-pressure separator gas, Oklahoma City	3	9
5. Constructed from analysis, gasoline from separator gas, Crescent well.	3	2
6. Constructed from analysis, gasoline from gas differentially liberated from 101 to 14 lb. Crescent well.	3	7
7. Constructed from analysis, gasoline from gas differentially liberated from 283 to 15 lb. Oklahoma City, same well as curve 4.		
8. Actual run of test car make. Gas tested 10.65 gal. per M. cu. ft. just after drip gasoline shown in curve 1 came off, and before drip shown in curve 3 came off	3 5	11 8
9. Actual run of 56.6° A.P.I. straight-run gasoline made from 38° A.P.I. Oklahoma City crude oil; 91 per cent off at 391° F.; end point 423° F.		

Table 3, lines 10 and 11, shows the characteristics of the gasoline that might be extracted from the gas from this same well, released by differential liberation between 283 and 15 lb. per sq. in. abs., after th gas had been released by flash liberation between a bottom-hole pressure of 2000 lb. per sq. in., more or less, and a well-head pressure of 1103 lb. per sq. in. abs., and differentially from this latter pressure down to 283 lb. per sq. in. abs. The product obtainable from this gas if all the N-butane in the gas is condensed is not a commercial product (line 10), but by reducing the N-butane content to 25 per cent by weight, a commercial product of characteristics shown in line 11 is obtained. An approximate distillation curve for such a gasoline is shown in Fig. 1, curve 7.

It is interesting to see the difference between the gasoline that might be extracted from the low-pressure separator (Table 3, line 9) and that which might be extracted from the gas from the sampling bomb (Table 3, line 11). When flash liberation extended all the way down to 265 lb. per sq. in. abs., the gas escaping from solution between 265 and 16 lb. per sq. in. abs. would produce a commercial gasoline of approximately 24 lb. vapor pressure having 34.1 per cent by liquid volume of hexane and heavier components. When differential liberation prevailed throughout the entire range of pressure drop between well-head pressure and atmosphere, the resulting gasoline having approximately the same vapor pressure would contain only 21.7 per cent by liquid volume of hexane and heavier components. The net yield, in gallons per 1000 cu. ft. of each of these products is about the same: 0.78 gal. per 1000 cu. ft. for the separator gas, and 0.65 gal. for the bomb gas, but differential liberation resulted in retaining in the oil sufficient hexane and heavier material to reduce the percentage of these components in the gasoline from 34.1 to 21.7 per cent.

Table 4 shows the results of analyses of gas from the separator and from the bottom-hole sampling bomb at the well in the Crescent field. The data on the separator gas were furnished by the operator. The data on the bomb gas were taken from Lindsly's[5] paper on these experiments. There was approximately 28 per cent more gas per barrel of oil escaping from the separator than was released by differential liberation from the bottom-hole sample. Since it is unlikely that any free reservoir gas was escaping from the well, this difference may be in part accounted for by the fact that the gas-oil ratio attributed to the separator gas was determined from field measurements of both gas and oil, which are not as accurate as the careful laboratory measurements to which the bomb sample was subjected. Table 3, lines 1 to 7, sets forth the probable characteristics of gasolines extractable from the gas from this well under different conditions of liberation from solution. If all the N-butane in the separator gas is condensed a large quantity of a very wild product is obtained (Table 3, line 1). If the N-butane content of this gasoline is reduced to 25 per cent by weight, a commercial product (Table 3, line 2) is obtained, having 29.2 per cent by liquid volume of hexane and heavier components. When differential liberation is applied throughout the entire pressure range, the gas liberated between 101 and 14 lb. per sq. in. abs. yields a commercial gasoline having 25.9 per cent by liquid volume of hexane and heavier; but the quantity of this gasoline is less than one-quarter of that obtained from the separator gas. Thus differential liberation throughout the entire range from bottom-hole pressure to atmosphere has resulted in retaining in the oil 79 per cent of the hexane and heavier components that were removed from solution in the oil by flash liberation of the gas. Approximate distillation curves of these two gasolines are shown in Fig. 1, curves 5 and 6. The gas released by differential liberation above 101 lb. per sq. in. abs. yielded only traces of any kind of gasoline (Table 3, lines 3, 4 and 5).

TABLE 4.—*Analyses of Gas Released from Solution under Different Pressure Conditions, Well at Crescent, Oklahoma*

Component	Gas from Separator[a]		Bomb Gas—Differential Liberation[b]					Excess of Separator Gas over Bomb Gas		
			Released		Total	Cu. Ft. per Bbl. Residual Oil				
	Per Cent by Volume	Cu. Ft. per Bbl. Residual Oil[c]	Above 101 Lb. per Sq. In. Abs.	Between 101 and 14 Lb. per Sq. In. Abs.		Test Conditions	Corrected to 60° F. 14.65 Lb. per Sq. In. Abs.	Cu. Ft. per Bbl. Residual Oil	Composition, Per Cent	Gasoline Fraction
O, N, and CO_2..	0.0158	17.1	0.0158	0.0000	0.0158	13.86	13.37	3.73	0.0151	
CH_4...........	0.6850	739.8	0.72763	0.00996	0.73759	646.87	623.84	115.96	0.4704	
C_2H_6...........	0.0677	73.0	0.06231	0.03852	0.10083	88.43	85.28	(12.28)		
C_3H_8...........	0.1045	112.9	0.03053	0.03902	0.06955	61.00	58.82	54.08	0.2194	
Iso-butane......	0.0226	24.4	0.01048	0.00812	0.01860	16.31	15.73	8.67	0.0352	
N-butane.......	0.0546	59.1	0.02097	0.01625	0.03722	32.64	31.48	27.62	0.1121	0.1121
C_5H_{12}..........	0.0319	34.5	0.00586	0.00971	0.01557	13.65	13.16	21.34	0.0865	0.0865
C_6H_{14}..........	0.01251	13.4	0.00030	0.00316	0.00346	3.03	2.92	10.48	0.0425	0.0425
C_7H_{16}..........	0.00392	4.2	0.00005	0.00098	0.00103	0.90	0.87	3.33	0.0135	0.0135
C_8H_{18}..........	0.00124	1.3	0.00001	0.00031	0.00032	0.28	0.27	1.03	0.0042	0.0042
C_9H_{20}..........	0.00033	0.3		0.00003	0.00003	0.03	0.03	0.27	0.0011	0.0011
Totals.......	1.0000	1080.0	0.87394	0.12606	1.00000	877.00	845.77	246.51	1.0000	0.2599

[a] Operator's records, measured at 60° F. and 14.65 lb. per sq. in. abs. Hexane and heavier component assumed to contain compounds in proportion to their vapor pressures at 30° C.

[b] B. E. Lindsly: Experimental Results from a Bottom-hole Sample, Crescent Pool, Oklahoma (In course of publication), maesured at 70° F. and 14.4 lb. per sq. in. abs. Hexane and heavier component broken down as above.

[c] Operator reports gas-oil ratio as 1080 cu. ft. per barrel based on tests prior and subsequent to experiment. Lindsly records approximately 900 to 1000 cu. ft. per barrel. Gas from separator shows 28 per cent more volume than gas released from solution by differential liberation on basis of operator's records; 18 per cent more on basis of Lindsly's records. Of excess of separator gas over bomb gas, 25.99 per cent is N-butane and heavier.

Mills and Heithecker[2] have shown that the gravity of crude oil can be substantially increased by increasing the amount of gas dissolved in it; and Lindsly has found that differential liberation of gas over a wide pressure range, by retaining in solution more of the lighter liquids while the fixed gases are removed, results in raising the gravity of the residual oil—that is, the oil in tanks—by from 1° to 3° A.P.I. Whereas it is not possible in practice to subject bottom-hole oil to differential liberation throughout the entire pressure drop, it is possible to approximate these conditions by multiple trapping. Thus, two separators can be installed at a well, which produces under single trapping, oil having a gravity of, say, 38° A.P.I. If the pressure on the high-pressure separator is carried at about 200 lb. and that on the low-pressure separator at about 10 bl., very little, if any, of the pentanes and heavier components of the gas-oil mixture will escape in the gas discharged from the high-pressure separator. See Table 3, lines 3, 4 and 5. The result is that more of them will be left in solution when the oil is discharged from the low-pressure separator. Such a procedure might readily raise the gravity of the oil more than 1° A.P.I. and mean considerable additional revenue to the property. However, if the gravity of the oil under single trapping is already above 40° A.P.I., there is no advantage in retaining still more of the lighter components in solution. It would be better to weather off the crude to a minimum gravity of 40° A.P.I. and sell the vapors thus produced to a gasoline plant, thus gaining revenue from the part of the original crude for which no premium is paid under present schedules.

An adaptation of multiple trapping is suggested in Fig. 3, in which an old bubble-type absorber is shown substituted for the low-pressure separator. The oil from the high-pressure separator is discharged into the inlet port of the absorber, into the top of which some of the gas from the high-pressure separator is expanded to furnish refrigeration. An old oil-field-type boiler forms the kettle for this stabilizer, and permits the oil to be heated if necessary. Enough pressure is assumed to be held on the absorber to throw the stabilized oil into the stock tanks. The remainder of the high-pressure gas is disposed of without further treatment, and the gas from the top of the absorber is delivered to the gasoline plant for treatment. This arrangement would cost very little, since nearly all companies have idle absorption equipment and old boilers on hand; and it would result in the delivery to the pipe line of a crude oil from which all of the permanent gases had been removed. The vapors thus made available for gasoline extraction will contain a much greater percentage of hexane and heavier components than where ordinary double trapping is in practice. Such vapors, sold to an outside gasoline plant, would command a higher royalty rate than could otherwise be obtained; and it is probable that even the gas from the low-pressure separator, where two are used, would command a higher rate of royalty than well-pressure gas. Thus even the operator who has not sufficient production in a field to warrant the installation of his own gasoline plant can derive some benefit from the reduced investment necessary on the part of the owner of the gasoline plant.

One of the most regrettable sources of waste in the early development of a property is the enormous volume of gas that is often vented to the air without treatment, while the management is trying to decide how large a gasoline plant to install, or whether or not to install one at all. Often from one to three years is required to reach this decision. There is always a great risk in building a gasoline plant in a new field, in that if it is built to handle all the gas available in the flush period of production a large part of this investment will be idle after this period has passed. A system of multiple trapping, or the stabilizing adaptation here suggested, would solve this dilemma. Small gasoline-extraction equipment could be installed very early in the life of the field, designed to treat only the gas discharged from the low-pressure separators. As conditions changed with declining production and gas volumes, and it became no longer feasible to continue double trapping, all the gas could be turned through the plant. By this time, however, the total volume of gas would probably not be greater than could easily be handled with the plant already in place, so that all of the investment in gasoline-extraction equipment could be kept active throughout the entire period of its existence; and all the gasoline that now is wasted to the air from new properties could be saved without risk of overbuilding the gasoline plant.

Royalty owners, lease operators and gasoline manufacturers would thus benefit directly and largely. It is a curious fact that the large quantities of gasoline that are allowed to escape during the early life of a field are viewed with so little concern, whereas very substantial sums are continually being expended in improving plant recovery efficiency to effect an increase in recovery negligible in comparison.

A much greater reduction in gasoline recovery facilities is possible than is indicated by the consideration of gas volumes alone. In absorber design provision has to be made for absorbing all the propanes and iso-butane from a mixture very rich in methane and ethane. The low-pressure separator gas contains relatively small amounts of methane and ethane, so that the propanes and the iso-butane are in higher concentration. Oil circulation, still and dephlegmator capacity and cooling capacity therefore can be still further reduced.

Another possibility that is suggested by the arrangement shown in Fig. 3, which would be practicable as long as there was a considerable volume of gas being discharged from the high-pressure separator, is the use of this gas to drive a compressor operating upon the gas from the low-pressure separator or the crude stabilizer. The high percentage of propanes and iso-butane in the low-pressure gas would make this peculiarly suited to vapor-phase stabilization. The expansion of the surplus high-pressure gas would provide refrigeration for knocking back the propanes for reflux purposes, and the heat of compression of the low-pressure gas would probably supply all the heat needed to operate the system. A gasoline plant of this nature could be installed at very small cost, as soon as sufficient gas became available to run one unit; and would represent a still further reduction in gasoline recovery equipment below the present conventional minimum.

In further illustration of the points raised by these solubility investigations, there are submitted some data dealing with a lease in the Glenn pool, in Creek County, Oklahoma. Fig. 2 gives a partial production history of this property. It is a lease of 160 acres in the central part of the field, and was fully developed prior to 1910. Vacuum was applied in 1913, and in 1928–29 approximately 26 in. of vacuum had been held on the wells for upward of 12 years. Production conditions have been practically uniform throughout the whole field for many years. The "plant yield" curve shown on Fig. 2 is the yield of the gasoline plant in the field, which took the gas from this lease along with about 20 times as much more gas from other nearby leases.

The most interesting point developed from Fig. 2 is the shape of the "plant yield" curve. The gas from this field increased in richness for several years after vacuum was applied, then rapidly declined from a peak of about 13 gal. per 1000 cu. ft. to a present rate of a little over 6 gal. per 1000 cu. ft. In the light of the recent studies under discussion, this condition would indicate:

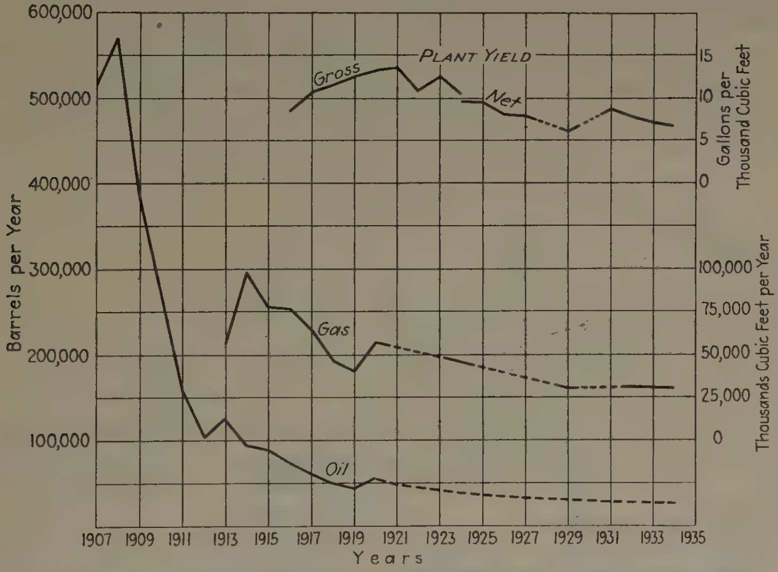

Fig. 2.—Partial production history of Glenn pool lease, from which drip gasoline samples shown in Table 4 were obtained.

Plant-yield curve is from gasoline plant running gas from this lease along with other Glenn pool gas. Note increase in plant yield and subsequent decrease, indicating complete exhaustion of light fractions.

1. The exhaustion of the original gas in the gas cap above the oil. This gas was released from solution differentially, and contained relatively large amounts of methane and ethane. As it was withdrawn from the gas cap, subsequent increments contained greater and greater proportions of the heavier components.

2. The removal from the reservoir oil of a large amount of the lighter fractions, which would have remained in solution at the reservoir temperature had not vacuum been applied.

3. The exhaustion from all the remaining oil of practically all of the permanent gases, so that the proportion of the heavier components which these gases will carry away from a heavy oil mixture is severely reduced. During the period of declining plant yield in this field there was observed a growing disparity between the theoretical gallons indicated by the sum of the products of the test yields at the various meters by the corresponding gas volumes, and the theoretical gallons indicated by tests at the plant master meter. The field tests were always in excess of the master meter test, and this difference was not compensated for by the collections of drip gasoline. This condition led to the study in which the drip gasoline data offered in Table 5 were collected.

In Fig. 1, curves 1, 2 and 3 show actual Engler distillations of three samples of drip gasoline collected on one day from three drips on the Glenn pool lease referred to above. Curve 8 is a distillation of the test-car make from gas from the A wells. Approximate analyses of these gasolines, inferred by reference to Pocock and Blair's analysis chart, are shown in Table 5, lines 4, 5, 6 and 8. This gas was tested at a point about 300 ft. from the vacuum station, and about 10 ft. downstream from the drip wherein was collected the drip gasoline shown in Fig. 1, curve 1. The test at this point was 10.65 gal. per 1000 cu. ft. About 1200 ft. farther downstream from the test point was located the drip from which the sample shown in Fig. 1, curve 3, was collected. The upstream sample was too heavy to have its characteristics included within the limits of the analysis chart for natural gasolines. The downstream sample was just light enough to fall on the chart, and an approximate analysis is given in Table 5, line 5. The drip gasoline shown in Fig. 1, curve 2, Table 5, line 6, was obtained from a drip located about 1500 ft. from the vacuum station serving the B wells on this same property.

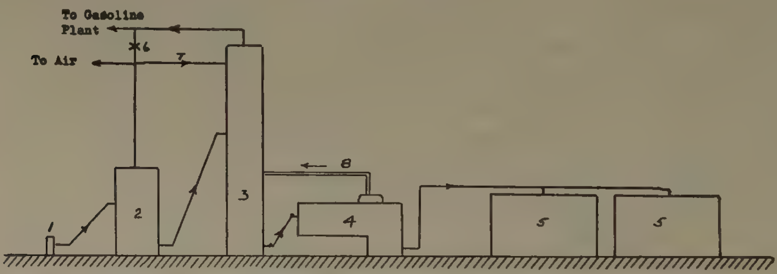

FIG. 3.—SUGGESTED MODIFICATION OF DOUBLE TRAPPING AT WELL, TO CONTROL GRAVITY OF OIL IN TANKS.

1. Well head.
2. High-pressure separator.
3. Bubble-type absorber, for stabilizer.
4. Oil-field type boiler for stabilizer kettle.
5. Stock tanks.
6. Gate on bypass.
7. High-pressure gas line to top of stabilizer.
8. Vapor line from kettle to stabilizer.

These analyses and distillation curves show the kind of material that is being pulled out of the Glenn pool crude as a result of the long-continued application of high vacuum. The gravity of the crude from this field has dropped from about 38° A.P.I. in the early life of the field to between 33° and 34° A.P.I. at present. These samples of drip gasoline condensed in the line at 10 in. of vacuum and at 45° F. The value of this liquid to the operator is greater as crude oil than it is as natural gasoline. This condition has prevailed for several years, and bids fair to continue. Were the Glenn pool being developed in 1934, instead of having been developed in 1908, it is hardly likely that an investigator in 1960 would find that the drip gasoline that was then condensing in the lines would have an initial boiling point of 100° F. and over.

TABLE 5.—*Distillation Characteristics and Inferred Analyses of Some Drip Gasolines from a Property in Glenn Pool, Okla., with Some Data on Gas in That Field*

	Gal. per Day[a]	M. Cu. Ft. per Day[a]	Gal. per M. Cu. Ft.[a]	Gravity, Deg. A.P.I.[b]	Percentage by Liquid Volume			Percentage Distilled Off		End Point, Deg. F.[b]
					Butanes, Pentane and Lighter[d]		Hexane and Heavier[d]	At 100° F.[b]	At 140° F.[b]	
Gas going to gasoline plant from lease:										
1. Group A wells	552	53.4	10.33							
2. Group B wells	408	46.7	8.73							
3. Total	960	100.1	9.59							
Drip gasoline: (c)										
From "A" wells:										
4. Caught 300 ft. from vacuum station	56			66.3	Cannot estimate from chart			0	11.0	313
5. Caught 1500 ft. from vacuum station	107			70.8	9.0	17.7	73.3	6	24.5	292
From "B" wells										
6. Caught 1500 ft. from vacuum station	219			70.4	11.0	16.9	72.1	6.5	20.0	272
Total drip gasoline:	382									
7. Total gasoline from lease	1,342									
8. Test-car make, gas from "A" wells tested 310 ft. from vacuum station			10.65	87.0	28.5	39.0	32.5	50.0	77.5	236

Initial gravities of oil in Glenn pool, 38° to 39° Bé. Gravities in November, 1927, 33° to 35° A.P.I. This lease yielded 11,900 gal. of drip gasoline in the month of November, 1927.

[a] Plant records, field measurements of gas, and actual settlement test of gas.

[b] Special distillation tests of drip gasoline, January, 1928.

[c] Special gages of drip gasoline from this lease, November, 1927. Drip condensed at 45° F. and 10 in. of vacuum from gas drawn from wells at 26 in. vacuum.

[d] Inferred analyses using Pocock and Blair's analysis chart for natural gasolines.

A comparison of the inferred analyses[6] of this drip gasoline produced by wells long subjected to high vacuum (Table 5) with the analyses of the reconstructed gasolines made from gas from wells still under high natural pressure (Table 3) shows the very high percentage of hexane and heavier fractions, 73 per cent in the drip gasolines as compared to 29 to 34 per cent in the others. The distillation curves of these two groups of products form two distinct groups on Fig. 1. It is interesting to note that the test-car make, Fig. 1, curve 8, from Glenn pool gas displays a distillation curve closely agreeing with the curves of the lighter group. The wide spread between the distillation curves of these two groups bears out the findings of the recent studies, pointing to selective solubility.

There is still much work to be done along these lines, which may be counted upon to be well worth its cost in money and effort; and it is hoped that this paper will suggest some new points for future investigation, as well as fulfill its patent purpose of pointing out the advantages already accrued.

References

1. D. B. Dow and C. E. Reistle Jr.; Absorption of Natural Gas and Air in Crude Petroleum. *Min. & Met.* (May, 1924) 336.
   C. E. Beecher and I. P. Parkhurst: Effect of Dissolved Gas upon the Viscosity and Surface Tension of Crude Oil. *Trans.* A.I.M.E. (1927) **77,** 51. Petr. Dev. and Tech.
   D. B. Dow and L. P. Calkins: Solubility and Effects of Natural Gas and Air in Crude Oil. U.S. Bur. Mines *R.I.* 2732.
   R. vanA. Mills and R. E. Heithecker: Volumetric and A.P.I. Gravity Changes due to the Solution of Gas in Crude Oil. U.S. Bur Mines *R.I.* 2893.
   W. N. Lacey: Experiments on the Rate of Solution of Gas in Oil. Inst. Petr. Tech. (August, 1931).
2. B. E. Lindsly: Solubility and Liberation of Gas from Natural Oil-Gas Solutions. U.S. Bur. Mines *Tech. Paper* 554.
3. S. Coleman, H. D. Wilde, Jr. and T. W. Moore: Quantitative Effect of Gas-oil Ratio on Decline of Average Rock Pressure. *Trans.* A.I.M.E. (1930) **86,** Petr. Dev. and Tech.
4. B. E. Lindsly: Note 2 above, 4.
5. B. E. Lindsly: Experiments on a Bottom-hole Sample at Crescent, Oklahoma. In course of publication.
6. L. A. Pocock and M. G. Blair: Graphic Analysis of Natural Gasoline. *Nat. Petr. News* (May 18, 1932) 37.

DISCUSSION

(*H. H. Power presiding*)

D. L. KATZ,* Bartlesville, Okla. (written discussion).—Mr. Morris points out seven specific directions in which fundamental information such as gas solubility may be of economic value to the petroleum industry. Most of these items involve large quantities of money, but if the fundamental studies would reliably solve one of the seven problems the cost of the investigation would be returned many fold. As research can assist in solving all of these problems, more attention and investment should be made in that direction.

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* Research Department, Phillips Petroleum Co.

One explanation of the lag of practical application of much of this fundamental work to crude oil production is the large amount of information necessary to properly handle a complex mixture such as crude oil. Often a research program must include preliminary work that cannot be directly applied, indicated in Mr. Morris' paper. Several of the items mentioned may be reliably treated but others require more fundamental study. For example, Mr. Coleman and coworkers presented their method of calculating oil reserves in 1929. I have read no publications enlarging and applying this method since that time. It has been only recently that data have been made available that would permit reliable estimates of this nature. Deviations of gaseous mixtures from ideal gases, as presented by Dr. Lacey and coworkers, and shrinkage values of reservoir crudes with gas liberation, which Mr. Lindsly has been finding, are a prerequisite for reliable prediction of oil and gas reserves.

The operation of the equipment for stabilizing the crude oil (Fig. 3) also illustrates the need of fundamental study. The economical advantage of the stage separation of gas from crude oil depends on equipment cost, maintenance of operation and separations accomplished. Could a man in the past have predicted the most economical operating conditions and equipment for such a procedure with any degree of precision? The behavior of methane in crude oil mixtures and deviations of other constituents from Raoult's law at high pressures even now are not fully evaluated. Data for the vaporization characteristics of the volatile constituents of crude oil, and methods of calculating fractionating equipment, are only in process of development, and little attention has been paid to the analyses of the liquid phase as well as the gas phase in studying separation problems.

In return for the efforts of the fundamental investigators who have had to take the long road to the economic utilization of their results, there have appeared many advantages, not all of which have been contemplated. Crude analyses and equilibria data provide the necessary tools for predicting the gasoline content of the vapor in the flash vaporizations mentioned in the paper. Also, gravities of the crude under any series of vaporizations may be predicted by this method. These tools make it possible to calculate many of the results previously obtained by long experiments. This improvement will facilitate the application of fundamental knowledge to the economic problems of the industry.

The predicting of the practicability of installing a gasoline plant in a field from a knowledge of the gas and gasoline vaporizing from a bottom-hole sample is an improvement over previous methods. However, an analysis of the bottom-hole sample along with vaporization calculations will give more readily the desired information. This method is more adaptable to general use and will be worth the extra effort required to develop it.

The application of our knowledge of the behavior of crude and gas mixtures to the economic problems of the industry should be stimulated in the direction Mr. Morris has shown us. No doubt many of the problems he discussed have been solved for individual cases by scattered investigators in the industry. The pooling of information and ideas will gradually make it possible for the industry as a whole to receive the economic benefits.

Only men who have had the experience of applying fundamental information to practical problems in the production industry realize the large gaps in our knowledge of the fundamentals. For this reason I should like to encourage the industry to continue basic investigations, which seem to be apart from immediate economic application. The value received from utilizing this information in the future in solving such problems as Mr. Morris has outlined will more than repay the industry.

Member.—What maximum pressure would the author recommend?

A. B. Morris.—I had in mind the analysis of the gas contained in well D in Oklahoma City field submitted by Mr. Lindsly. It contained only traces of commercial gasoline. The determination of the best pressure would have to include a study of each particular pool and well. From the data submitted by Mr. Lindsly, I cannot see that the double high stage accomplishes any more than the single. The volume of gas to be handled probably would never pay out an investment.

R. J. Schilthuis,* Houston, Texas.—As the author points out, the investigations on the advisability of the installation of vapor recovery systems are usually postponed until, figuratively speaking, the "horse is stolen." Studies on subsurface samples of oil and gas would shed a great deal of light, very early in the life of a field, on whether or not a vapor recovery system would be profitable.

One of the most important questions in such investigations, particularly where the A.P.I. gravity enters into the price paid for the crude, concerns the effect of the recovery system on the gravity of the crude. It might be possible that in some instances the profits accrued through the vapor recovery system would be entirely overbalanced by a lowering of the gravity of the crude, so that the crude would fall into a lower price bracket.

A. B. Morris.—The general feeling is that as much gasoline is allowed to go to waste in the early life of a field as is recoverable later on.

Member.—The necessity of getting bottom-hole samples early in the life of a pool should again be stressed. If more attention were paid to the constitution of the hydrocarbons of the gases and to bottom-hole samples, time and money would be saved.

H. H. Power,† Tulsa, Okla.—Several years ago, Mr. Morris and I were engaged in the estimation of oil reserves; in particular, the value of casinghead gas contracts. His paper now under discussion presents new methods supplementing the old whereby gasoline yields from casinghead gas may be estimated for various periods in the decline of oil wells. Solubility data are particularly valuable in the early stages of pool development when plans are being laid for the construction of gasoline plants. An estimate of the probable gasoline reserves is essential to the design of plants of correct size and type to adequately process casinghead gas at a maximum profit over the life of the field. In various ways, Mr. Morris has exhibited the practical uses to which solubility investigations can be economically applied.

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Fundamental Operating Pressures in Oil-gas Reservoirs

By Eugene A. Stephenson,* Member A.I.M.E.

(Tulsa Meeting, October, 1934)

In November, 1932, Dr. Lacey, of the California Institute of Technology, presented before the American Petroleum Institute some of the results of his research under Project 37[1]. The investigations described dealt particularly with changes in the physical properties of petroleum that result from the solution of natural gas therein.

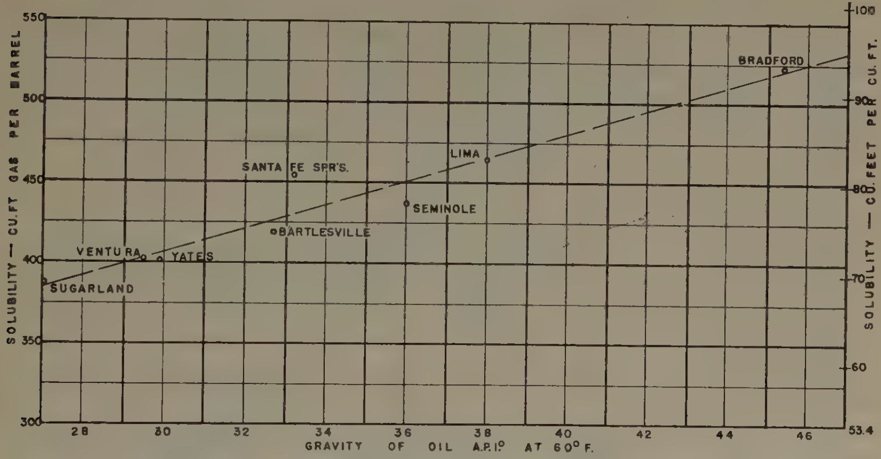

Fig. 1.—Solubility of Santa Fe Springs dry gas in various crude oils. 100° F. and pressure 2000 lb. per sq. in. (*After Lacey.*)

The solubility of Santa Fe Springs dry gas, containing 87 per cent methane, 8 per cent ethane and 5 per cent propane, had been determined in various crudes at 100° F., and 2000 lb. pressure per square inch as shown in Table 1 and Fig. 1 herewith. Originally the computations were made in terms of cubic feet per barrel, but for a more uniform basis of comparison the results are also shown as cubic feet of gas[2] per cubic foot of oil.

Manuscript received at the office of the Institute Feb. 19, 1935.

* Professor of Petroleum Engineering, Missouri School of Mines and Metallurgy, Rolla, Missouri.

[1] W. N. Lacey: Practical Benefits of Pressure Maintenance in Petroleum Production. *Oil Weekly* (Jan. 9, 1933) **68**, No. 4, 19.

[2] Unless otherwise stated, the volume of the gas, wherever mentioned in this paper, is measured at 14.73 lb. per sq. in. and 60° F.

TABLE 1.—*Solubility of Santa Fe Springs Dry Gas in Various Crude Oils*
At a Temperature of 100° F. and a Pressure of 2000 Lb. per Sq. In. (After Lacey)

Source of Oil	Gravity, Deg. A.P.I.	Solubility	
		Cu. Ft. per Bbl.	Cu. Ft. per Cu. Ft.
Sugarland, Tex	27.1	389	69.28
Yates, Tex	29.9	401	71.42
Ventura, Calif	29.5	402	71.60
Bartlesville, Okla	32.7	418	74.45
Seminole, Okla	36.0	437	77.83
Santa Fe Springs, Calif	33.2	454	80.86
Lima, Ohio	38.0	464	82.64
Bradford, Pa	45.4	522	92.97

Previous investigations along similar lines, but through more restricted pressure ranges, had been made by Beecher and Parkhurst[3], Dow and Calkin[4], and several others[5], and some of these results, together with those

TABLE 2.—*Compositions of Gases Used in Experiments Represented in Figure* 2

Graph No.	1[a]	2	3	4	5	6
Investigator	Lindsly	Beecher-Parkhurst	Lacey	Dow-Calkins	Beecher-Parkhurst	Frolich-Tauch, et al
Gravity of oil, deg. A.P.I.	62.6	35.4	33.2	31.0	35.4	Gas-oil
CH_4	66.1	52.0	87.0	98.3	82.5	100
C_2H_6	16.1	39.0	8.0		5.5	
C_3H_8	11.3		5.0			
C_4H_{10}	5.2					
C_5H_{12}	1.3					
CO_2		1.2		1.0	5.9	

[a] This graph shows only the volume of methane in the solution; at the maximum pressure the total quantity of dissolved gas had the composition indicated.

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[3] C. E. Beecher and I. P. Parkhurst: Effect of Dissolved Gas Upon the Viscosity and Surface Tension of Crude Oil. Petr. Dev. and Tech. in 1926, A.I.M.E. (1927) 51–69.

[4] D. B. Dow and L. P. Calkin: Solubility and Effects of Natural Gas and Air in Crude Oils. U. S. Bur. Mines *R. I.* (1926) 2732.

[5] D. B. Dow and C. E. Reistle, Jr.: Absorption of Natural Gas and Air in Crude Petroleum. *Min. & Met.* (May, 1924) 336.

B. E. Lindsly: Preliminary Report on Bureau of Mines Investigation Regarding the Solubility of Natural Gas in Crude Oils. *Trans.* A.I.M.E. (1931) **92**, 251–278.

P. K. Frolich, E. J. Tauch, J. J. Hogan and A. A. Peer: Solubilities of Gases in Liquids at High Pressure. *Ind. & Eng. Chem.* (1931) **23**, No. 5, 548–550.

of Dr. Lacey, are shown in Fig. 2. The composition of the gases and the character of the oils used in the experiments are given in Table 2.

Dr. Lacey and his associates also extended the work of previous investigators and studied the relation between pressure and solubility of Santa Fe Springs dry gas throughout a pressure range extending from atmospheric to approximately 2500 lb. per sq. in. The oils used were Santa Fe Springs crude, Crystal oil, and several others, and parts of the results have been published through various media[6].

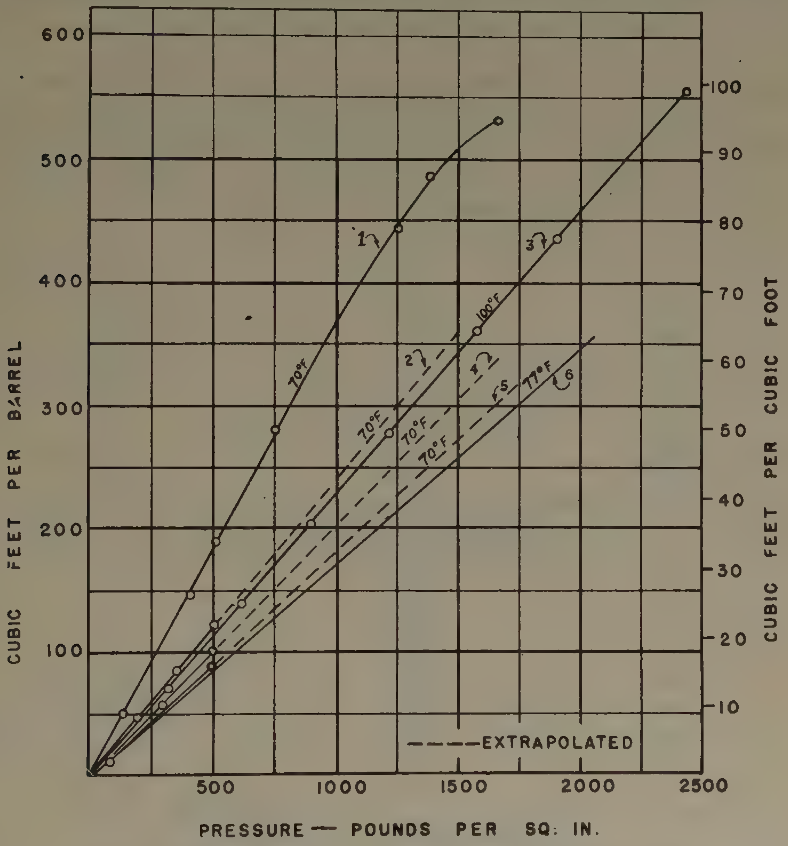

FIG. 2.—SOLUBILITIES OF VARIOUS GASES IN CRUDE OILS.

The particular physical properties of the oil-gas solutions investigated by Dr. Lacey and his associates included surface tension, viscosity, and specific gravity, through the same temperature and pressure ranges as the solubility studies.

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[6] W. N. Lacey, B. H. Sage and C. E. Kircher, Jr.: Phase Equilibria in Hydrocarbon Systems, III.—Solubility of a Dry Natural Gas in Crude Oil. *Ind. & Eng. Chem.* (June, 1934) **26**, 652.

B. H. Sage, W. N. Lacey and J. G. Schaafsma: Phase Equilibria in Hydrocarbon Systems, IV.—Solubility of Propane in Two Different Oils. *Ind. & Eng. Chem.* (August, 1934) **26**, 874.

Interest in the published graphs led to an inquiry requesting specific data, to which Dr. Lacey most generously responded[7] with two sets of pressure, solubility-viscosity data at 100° F., and one set at 140° F. Similar data for 200° F. were included, but because of the tendency of some of the liquid to pass into the vapor phase at this

TABLE 3.—*Solubility of Santa Fe Springs Gas in Santa Fe Springs Crude*

Pressure, Lb. per Sq. In.	Absolute Viscosity, Millipoises[a]	Solubility, Volume of Gas (At 60°F. and 14.73 Lb. per Sq. In., per Unit Volume of Oil)
	EXPERIMENT NO. 1, AT 100° F.	
0	44.3	0
270	35.3	10.8
621	26.8	24.9
790	22.8	31.7
1014	20.9	40.7
1339	16.7	53.7
1615	14.7	64.8
2022	12.48	81.1
2427	10.88	97.4
	EXPERIMENT NO. 2, AT 100° F.	
0	44.3	0
274	38.9	11.0
470	31.4	18.9
857	25.2	34.4
959	22.7	38.5
1209	18.9	48.5
1363	16.7	54.7
2275	11.6	91.3
2444	11.0	97.8
	EXPERIMENT NO. 3, AT 140° F.	
0	24.35	0
330	$\underline{21.80}$–22.00	10.8
566	17.76–$\underline{17.8}$	18.5
767	16.12–$\underline{16.5}$	25.1
1142	13.25–$\underline{13.6}$	37.4
1550	11.60–$\underline{11.70}$	50.7
1886	$\underline{10.8}$ –10.9	61.7
2209	$\underline{9.9}$ –10.25	72.3

[a] The underlined figures are those designated by Dr. Lacey as most accurate.

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[7] Personal communication.

temperature their accuracy was not considered by Dr. Lacey on a par with the 100° F., and 140° F., studies, and they are not shown herewith.

Table 3, shows the data provided by Dr. Lacey; the relations between pressure and solubility for the two temperatures used are shown in Fig. 3.

In order to facilitate a more thorough study of the viscosity-solubility phenomena, empirical equations based on these data have been developed, which express the relations between viscosity and either the pressure or the quantity of gas dissolved per unit volume of oil. One such equation, which fits the experimental data closely, takes the following general form[8]:

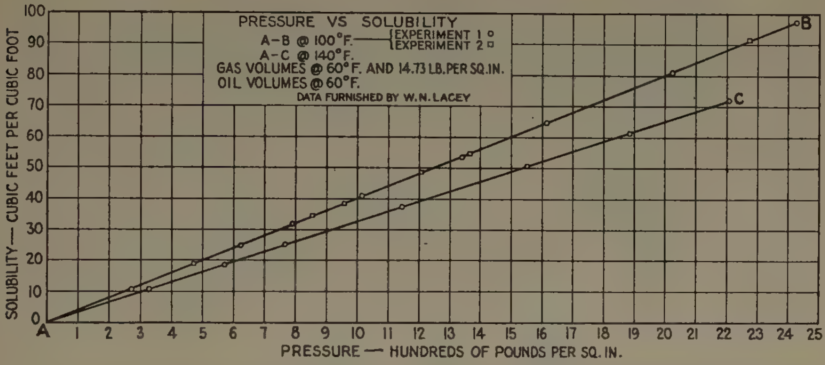

FIG. 3.—SOLUBILITY OF SANTA FE SPRINGS DRY GAS IN SANTA FE SPRINGS CRUDE OIL.

$$y = ae^{\frac{b}{x+c}} \qquad [1]$$

where y = viscosity in millipoises and x = solubility in cubic feet of gas per cubic foot of oil.

The values of the parameters in these empirical equations are as follows:

	AT 100° F.	AT 140° F.
$a =$	1.85	1.275
$b =$	382.8	454.3
$c =$	119.3	153.8

Hence the equations for the experimental results are:

$$\text{At } 100^\circ \text{ F. } y = 1.85e^{\frac{382.8}{(+119.3)}} \qquad [2]$$

$$\text{At } 140^\circ \text{ F. } y = 1.275e^{\frac{454.3}{(x+153.8)}} \qquad [3]$$

Curve *A-B* of Fig. 4 shows the smoothed curve of equation 2 and curve *C-D* shows the smoothed curve of equation 3.

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[8] The writer is indebted to Mr. E. S. Burnett of the U.S. Bureau of Mines for suggesting this form of equation.

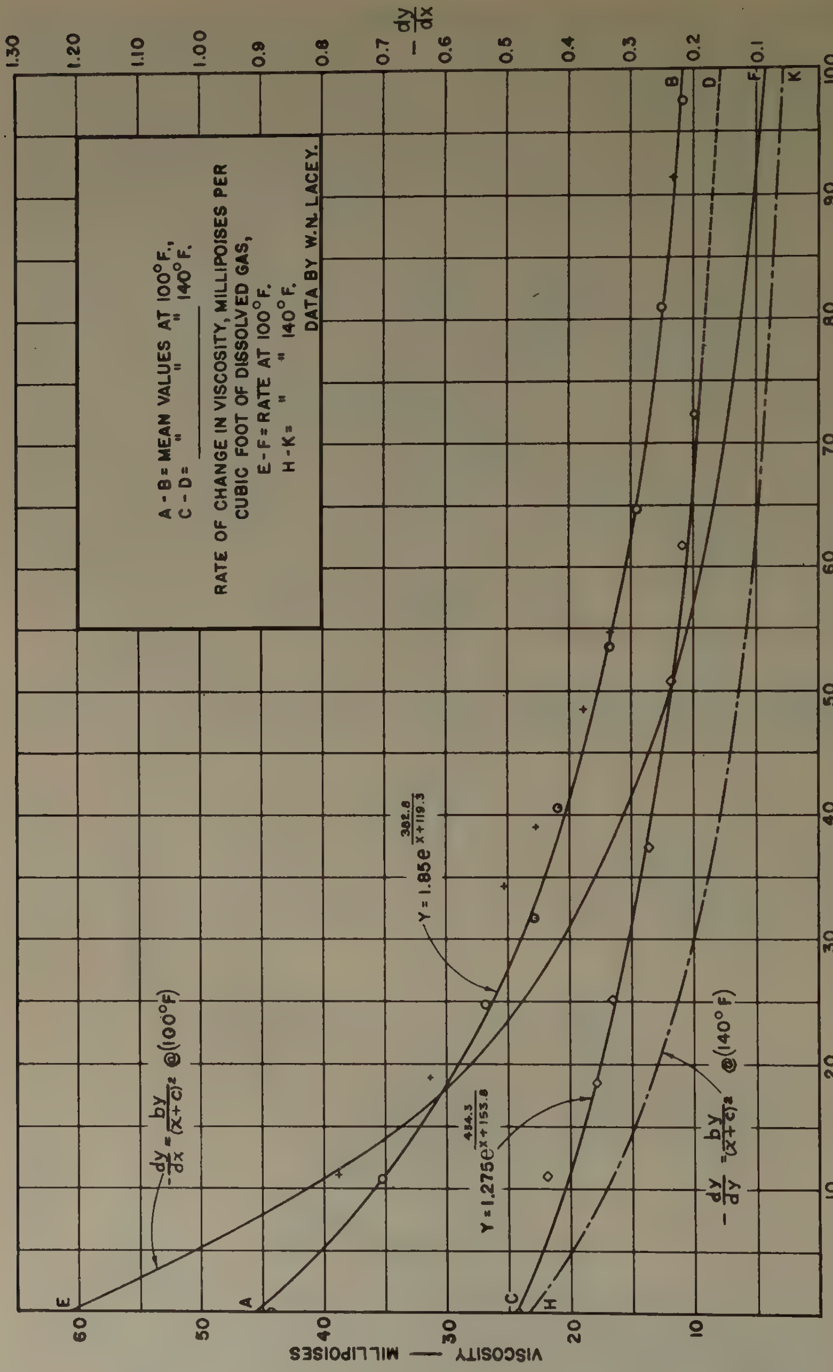

Fig. 4.—Relation between solubility and viscosity, Santa Fe Springs dry gas in Santa Fe Springs crude.

The rate of change in viscosity per unit change in quantity of dissolved gas is obtained by differentiating these equations, and the results have the general form:

$$-\frac{dy}{dx} = \frac{b}{(x+c)^2} \cdot ae^{\frac{b}{(x+c)}} = \frac{by}{(x+c)^2} \qquad [4]$$

The values of these functions are shown by curves *E-F* and *H-K* of Fig. 4.

Corresponding values of pressure, solubility, viscosity and rate of change in viscosity are shown in the Table 4. The values in the first half of Table 4 have been chosen arbitrarily from the graphs at intervals corresponding to pressure changes of 250 lb. per sq. in.; they are equivalent to intervals of 10 cu. ft. of dissolved gas per cubic foot of oil.

TABLE 4.—*Values Corresponding to Graphs of Figure* 4

Pressure, Lb. per Sq. In. Abs.	Solubility of Gas, Cu. Ft. per Cu. Ft.	Viscosity, Millipoises (Calculated)	Rate of Change in Viscosity, Millipoises per Cu. Ft. of Dissolved Gas
At 100° F., $y = 1.85e^{\frac{382.8}{x+119.3}}$			
0	0	45.7	1.229
250	10	35.8	0.819
500	20	28.9	0.570
750	30	24.1	0.414
1000	40	20.5	0.309
1250	50	17.7	0.237
1500	60	15.6	0.186
1750	70	13.9	0.148
2000	80	12.6	0.121
2250	90	11.5	0.100
2500	100	10.8	0.086
At 140° F., $y = 1.275e^{\frac{454.3}{x+153.8}}$			
0	0	24.36	0.467
305	10	20.40	0.345
610	20	17.34	0.261
915	30	15.05	0.202
1221	40	13.25	0.160
1526	50	11.81	0.129
1831	60	10.65	0.106
2136	70	9.69	0.088
2442	80	8.87	0.074
2746[a]	90	8.21	0.063
3051[a]	100	7.65	0.054

[a] Extrapolated.

INTERPRETATION OF RESULTS

Bearing in mind the limited scope of the experimental work, the hazards of general conclusions are well known, particularly where extrapolation of the curves might be attempted, or other temperatures considered. It is therefore emphasized at this point that the results are purely a laboratory study involving a relatively simple gas, one oil and but two temperatures, that oil-field gases are, as Lindsly has shown[9], far more complex and that the phase relationships are only partially known. Hence the interpretations apply only to these particular cases.

However, the significant conclusion that can safely be drawn from these experiments and their mathematical analyses is, that *at high pressures, or with large quantities of gas already dissolved per unit volume of oil, unit changes in pressure have extremely small effects upon the physical properties of the oil, while much more pronounced effects are caused by similar pressure changes at low pressures.*[10] These results can be viewed either from the standpoint of repressuring operations or from the standpoint of pressure reduction in a newly discovered pool.

For example, with the particular oil and gas used by Dr. Lacey, at 100° F. and approximately 2500 lb. per sq. in., a change in pressure of 25 lb. causes one cubic foot of gas to escape from or go into solution in one cubic foot of oil. The resultant change in the viscosity is only 0.085 millipoise. At 1500 lb. per sq. in., a change in pressure of 25 lb. causes a similar change in the amount of dissolved gas per cubic foot of oil, but the change in viscosity is 0.19 millipoise. At 750 lb. per sq. in., the same changes in pressure and solubility alter the viscosity 0.41 millipoise. At 250 lb. per sq. in., the corresponding change in viscosity is 0.82 millipoise. Expressed another way, the viscosity of Santa Fe Springs crude at 100° F. can be reduced 50 per cent (from 44.7 to 22.4 millipoises) by dissolving 35 equivalent volumes of Santa Fe Springs dry gas in it, but in order to reduce the viscosity another 50 per cent (from 22.4 to 11.2 millipoises), 65 more equivalent volumes of gas must be forced into solution, at a pressure of nearly 2500 lb. per square inch.

Similarly at 140° F. and 2440 lb. per sq. in. a change in pressure of 30.5 lb. per sq. in. is accompanied by a change in the solubility of the gas of one cubic foot per cubic foot of oil, and the resultant change in viscosity is 0.074 millipoise. A similar change in the amount of dissolved gas at pressures of approximately 1500 lb. per sq. in. causes a change in viscosity of 0.13 millipoise. At a pressure of 750 lb. per sq. in., the viscosity change that accompanies the 30.5 lb. pressure change is 0.236 millipoise. At 250 lb. per sq. in., the corresponding change in viscosity is 0.35 millipoise, or five times as much as at 2440 lb. Expressed as above, 46 cu. ft. of gas are required at 140° F. to reduce the viscosity by 50 per cent (or from 24.3 to 12.2 millipoises), while 162 additional cubic feet (extrapolated value) would be needed to bring about a further 50 per cent reduction in the viscosity.

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[9] B. E. Lindsly: Solubility and Liberation of Gas from Natural Oil-Gas Solutions. U.S. Bur. Mines *Tech. Paper* 554 (1933).

[10] Similar results were reported by D. T. Jones: The Surface Tension and Specific Gravity of Crude Oil under Reservoir Conditions. World Petroleum Congress, July 19–25, 1933.

To carry the illustrations a little further, a pressure drop from 2500 to 2000 lb. per sq. in., at 100° F., produces an increase in viscosity of 1.7 millipoises (from the viscosity that is approximately that of water at 60° F.), but a similar drop from 1000 to 500 lb. per sq. in. increases the viscosity 7.4 millipoises, or 4.3 times as much. At 140° F., a drop of 600 lb., from 3000 lb. per sq. in., increases the viscosity 1.25 millipoises, but the drop from 1200 to 600 lb. per sq. in. increases it 4.09 millipoises.

Graphs *A-B* and *C-D* of Fig. 4 indicate that a rise in temperature of 40° F. has practically the same effect on the viscosity of the oil as the presence of approximately 30 to 35 cu. ft. of dissolved gas, and that the rate of change and the total change in viscosity for a given pressure or volume of gas is much less at the higher temperature.

From the practical standpoint it is well to keep steadfastly in mind the fact that viscosity is a measure of internal friction[11], that doubling the viscosity means doubling the internal friction, and hence, other things being equal, twice as much work will be required to move a unit weight of the more viscous oil through a given distance and a given cross-sectional area of sand. Where low rates of flow are involved, permeability is proportional to both velocity and viscosity[12], and since the specific gravity of the oil also rises as the volume of dissolved gas falls, both viscosity and gravity increase (unless compensated by volumetric changes) tend to increase the amount of work that must be performed in moving a unit volume of oil through a given distance.

Further, the gases that escape from solution in the oils at high pressures carry larger proportions of the lighter constituents than those which come off at lower presures[13]. Since a relatively simple gas has been found to exert a pronounced influence on the physical properties of the associated oil, it is reasonable to anticipate that some of the heavier, more soluble hydrocarbons, such as propane, butane, etc., will have greater effects per unit pressure change upon the physical properties of crude oils than the lighter ones. This leads to the tentative suggestion that in actual reservoirs the changes that take place in the properties of the crudes at low pressures may be even more marked than would appear from the experimental work thus far available, and the ultimate recoveries may be affected much more by unit pressure changes at low pressures than at high pressures. To put this statement in some quantitative form, a drop in pressure from 2500 to 2000 lb. per sq. in., in comparison with the drop from 1000 to 500, may have an almost negligible influence upon the properties of the crude that affect the total or ultimate recovery. (The part played by mixtures of gas bubbles and oil is temporarily ignored.)

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[11] R. D. Wyckoff, H. G. Botset, M. Muskat and D. W. Reed: Measurement of Permeability of Porous Media. *Bull.* Amer. Assn. Petrol. Geol. (1934) **18,** No. 2, 161–190.

G. H. Fancher, J. A. Lewis and K. B. Barnes: Some Physical Characteristics of Oil Sands. The Pennsylvania State College Bulletin, *Bull.* 12 (1933) 65–168.

[12] R. D. Wyckoff, H. G. Botset, M. Muskat and D. W. Reed. Reference of footnote 11, 162.

[13] B. E. Lindsly: Solubility and Liberation of Gas from Natural Oil-gas Solutions. U.S. Bur. Mines *Tech. Paper* 554 (1933) 29, 31, 59, 63, etc.

The writer ventures to call attention to the fact that in natural reservoirs the relations between pressure, quantity of dissolved gas, and the physical properties of the oils are really quite fortuitous. Merely because a reservoir happens to contain an oil saturated with certain gases, at a definite pressure, which may or may not be related to the saturation pressure, is by no stretch of the imagination a reason for considering either the initial pressure or the composition of the gas as the ideal ones, in so far as recovery of the reservoir contents is concerned. Neither is it sound to ignore the reservoir pressure and consider only some convenient operating pressure—or its related sand-face pressure—that will produce an arbitrary gas-oil ratio. The latter may take into consideration only the lifting efficiency and the market conditions, and disregard events within the reservoir itself, events that are certain to affect the properties of both the oil and the gas and probably their ultimate recovery. At the present time it appears to be beyond the realm of our technical skill to increase the pressure, temperature or gas content of a newly discovered pool, but maintenance and restoration of pressure, with their concomitant results are effectively employed in partially depleted pools.

However, the special purpose of this article is to urge that the use of either of these methods should be based on experimental data, such as Lacey, Lindsly, Jones and others have shown can be obtained. The magnitude of the pressures should be ascertained which produce such favorable or ideal physical properties of the reservoir contents as will yield the largest recoveries thereof, consistent with economic factors. Fortunately the development of bottom-hole sampling and recording devices has placed at the disposal of the engineer part of the necessary equipment with which to investigate this fascinating field.

It may be possible that further experimental work will show that relations can be established between solubility, compressibility, temperature, composition of the oil and gas, molecular weights of the various constituents, and the rates of change in physical properties. From the standpoint of the engineer, the oil operator and the public interest, the correct time to discover these mutual relationships is at the beginning of the development of the field, or date of discovery. Sound engineering dictates that the relations between pressure, solubility, viscosity, surface tension, adhesion tension, specific gravity, etc., be studied at the time the reservoir is tapped, if the base for ideal development and operating conditions is to be established on as broad a foundation as possible. Even if no use is made of the information during the early stages of development of a field, it should be acquired then, since both the spread of unitization and the demand for better recoveries will tend to foster more extensive use of technical data.

ACKNOWLEDGMENTS

Grateful acknowledgment is herewith made to Dr. William N. Lacey and his associates at the California Institute of Technology, who have generously provided the data on which this paper is based; to E. S. Burnett, of the U.S. Bureau of Mines, who has made numerous constructive criticisms, and to Prof. R. M. Rankin, of the Missouri School of Mines and Metallurgy, who has checked the mathematical interpretations.

An Approximate Theory of Water-coning in Oil Production

By M. Muskat* and R. D. Wyckoff*

(Tulsa Meeting, October, 1934)

The phenomenon called "water-coning" is that, observed in many oil wells, in which bottom water gradually and frequently suddenly displaces a part or all of the oil production when a certain rather critical production rate from the well is exceeded. To follow in detail the process of the formation of a water cone as it breaks through the oil zone and enters the well bore is a problem so complex as to make a theoretical analysis practically impossible. However, an analytical treatment of the flow system before the water has broken through and during the time that it lies statically beneath the oil zone with an elevated or "coned" surface can be carried through under certain approximations. To present an analysis which shows the essential characteristics of the coning mechanism is the purpose of the present discussion.

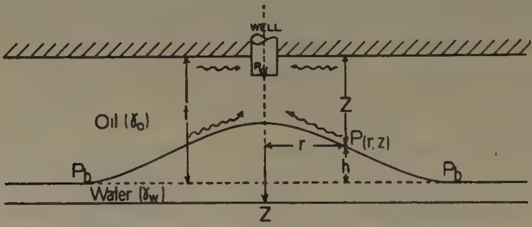

Fig. 1.—Homogeneous sand formation with upper portion saturated with oil and lower portion with water.

Physical Basis of Theory and Meaning of Approximations

As will always be true for flow systems where true water-coning is at all possible, the water will be supposed to lie beneath the oil zone because of its density contrast with respect to the oil. In fact, under the usual field conditions, when the pay horizon is reasonably homogeneous, the water most frequently enters the well through the lower zones, but even when it enters from intermediate zones it may, in the later life of the well, displace the bottom layers of oil, thus resulting in a system wherein the oil is effectively floating on the water.

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Fig. 1 represents a homogeneous sand formation in which the upper portion is saturated with oil and the lower portion with water. The phase of the problem with which the present analysis will be concerned is the condition under which oil may flow into the well without the production of water. This obviously requires that the water assume a condition of static equilibrium. In particular, the pressures at datum t must everywhere be equal to the constant hydrostatic pressure in the water zone that may be taken as the formation or reservoir pressure, P_b, as measured at the bottom of the oil horizon at a point remote from the well.

This means that: $p(r, z) + \gamma_w g(t - z) = P_b$ [1]

or:

$$p(r, z) + \gamma_w gh = P_b \qquad [1a]$$

where $p(r, z)$ is the pressure in the oil immediately above the surface of the water at the point (r, z); γ_w is the density of the water, and γ_o, which will be referred to later, is the density of the oil; g is the acceleration of gravity, and t the thickness of the oil horizon.

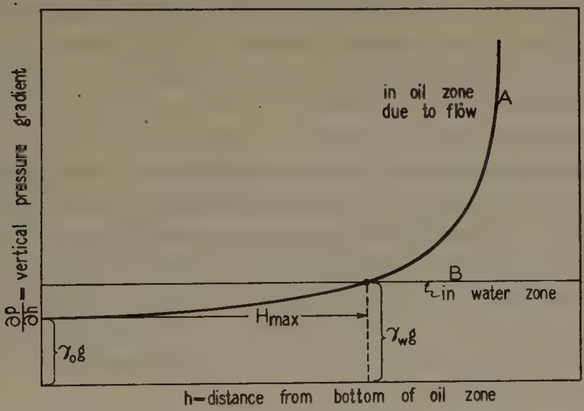

FIG. 2.—ILLUSTRATION OF EQUILIBRIUM AT WATER SURFACE.

Equations 1 or 1a represent a necessary equilibrium condition if the water cone is to remain in a static condition below the oil zone while flow occurs in the latter zone. Physically it means that if the drop in pressure below reservoir pressure at any point, as P, in the vicinity of the well equals the differential hydrostatic head $gh(\gamma_w - \gamma_o)$, a water column rising to that point would be in static equilibrium. However, from this same physical picture it appears that another condition must be satisfied in order to maintain dynamical equilibrium at the water surface. Thus each particle of water at the oil-water interface is acted upon by the pressure gradient present in the immediately adjacent oil zone, since this boundary represents a limiting streamline of the oil zone. Because the flow is convergent, this pressure gradient increases rapidly in the immediate vicinity of the well in a manner qualitatively indicated by curve A,

Fig. 2. In the water zone, on the other hand, there is a constant downward vertical pressure gradient due to the acceleration of gravity shown as curve B, Fig. 2. It is clear that from this point of view, at a height of cone indicated as $H_{\max}$, the pressure gradient in the oil zone is just equal to the opposing differential gravitational force acting upon the water and that any slight increase in the height of the water cone above this point will result in flow of water into the well. Thus from these simple qualitative considerations a critical height of cone as at $H_{\max}$ is indicated. Further justification of this conclusion will be presented later.

ANALYTICAL DEVELOPMENT

Returning now to equations 1 and 1*a*, it is evident that their solution requires a knowledge of the pressure function $p(r, z)$. This pressure distribution, on the other hand, depends upon the shape of the cone surface, which acts as an impermeable boundary to the flow of the oil. Unfortunately, however, the simultaneous determination of the pressure distribution and the shape of the cone is too difficult a problem to permit an explicit solution and one is forced to assume the value of $p(r, z)$ and then solve equation 1 for the corresponding cone surface $z = z(r)$. The simplest assumption as to the nature of the pressure distribution, and the only one that seems amenable to analytical treatment without undue labor, is that it is effectively the same as that for the case where there is no cone and the oil is flowing in a sand between two parallel impermeable boundaries and into a well partly penetrating the sand. However, before applying this pressure distribution to the solution of equation 1, it is convenient to transform the condition of equilibrium as follows.

Introducing the notation:

$$\Phi = \frac{k}{\mu}(p - \gamma_0 gz);\ \Delta\Phi = \Phi - \Phi_w = \Phi - \frac{k}{\mu}p_w$$

$$\Delta P = P_t - p_w = P_b - \gamma_0 gt - p_w;\ \Delta\gamma = (\gamma_w - \gamma_0) \tag{2}$$

where Φ is the potential function in the oil zone and ΔP is the total pressure drop in the oil zone as measured at the top of the sand, equation 1 may be rewritten as:

$$\Delta\Phi(r, z) = \frac{k}{\mu}\Delta P - \frac{k}{\mu}g\Delta\gamma(t - z) \tag{3}$$

Observing that for large r, $\Delta\Phi = \frac{k}{\mu}\Delta P \equiv (\Delta\Phi)_e$ we finally have:

$$\frac{\Delta\Phi(r, z)}{(\Delta\Phi)_e} = 1 - \frac{g\Delta\gamma(t - z)}{\Delta P} \tag{4}$$

To determine the solutions of this equation the values of the functions $\Delta\Phi$ and $(\Delta\Phi)_e$ must be known. These, as has already been mentioned, will be taken as those corresponding to a cone-free system in which a well partly penetrates a sand with horizontal and parallel faces. From the detailed analysis of such systems[1] it has been found that for all practical purposes $\Delta\Phi$ may be expressed by an equation of the form:

$$\Delta\Phi = q\{\Phi_e - \Sigma a_n \Phi_0(b_n\, r, z)\} \qquad [5]$$

where q is an arbitrary coefficient independent of r and z, Φ_e is a constant dependent upon the well radius r_w and the depth of well penetration, b, b_n is the depth of a hypothetical flux element of density a_n extending from the top of the sand to the point $z = b_n$, and $\Phi_0(b_n, r, z)$ is the contribution of such an element to the resultant potential distribution. The only approximation involved in equation 5 is that the summation sign has replaced an integration.

It may be shown further that:

$$(\Delta\Phi)_e = q\left\{\Phi_e - \frac{4}{t}\Sigma a_n b_n \log \frac{4t}{r_e}\right\} = \frac{k}{\mu}\Delta P \qquad [6]$$

where r_0 is the effective formation radius. No simple rule can be given for determining directly the terms $a_n\Phi_0(b_n, r, z)$; rather, they can be obtained only by going through the details of the analysis.

Making use, then, of these results, one finally obtains as the equation of the surface of the cone:

$$\Sigma a_n \Phi_0(b_n, r, z) = A + \frac{B}{\Delta P}\left(1 - \frac{z}{t}\right), \qquad [7]$$

where: $$A = \frac{4}{t}\Sigma a_n b_n \log \frac{4t}{r_e};\ B = gt\Delta\gamma(\Phi_e - A). \qquad [7a]$$

In using equation 7, it is assumed, of course, that the terms on the left-hand side are known from a solution of the simplified potential problem, and that the physical constants of the system are also known; namely, the formation boundary radius r_e, the sand thickness t and the density difference $\Delta\gamma$. Choosing, then, the penetration of the well for which the cone is to be determined and the pressure differential ΔP, it can be supposed that all the coefficients in equation 7 are known numerically, and the problem that remains is simply that of solving the equation for z at the chosen value of r. This may be done most readily by first plotting the left-hand side as a function of z and then finding the intersection of the curve so formed with the straight line representing the right-hand side.

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[1] M. Muskat: *Physics* (1932) **2**, 329.

To illustrate the process more clearly, the left side of equation 7 has been plotted as a function of $\frac{z}{t}$ in curve I of Fig. 3, for the particular case given by $r = 0$, $r_w/t = \frac{1}{500}$, $r_e/r_w = 2000$, and a well penetration of 25 per cent. The numerical values of $\Sigma a_n \Phi_0$ were obtained from the paper cited above and must, in general, be determined by a preliminary analysis of the potential distribution in the cone-free system. From the assumed value of $\frac{r_e}{t}$, $A = 0$, and the right side of equation 7 is represented by a straight line intersecting the $\frac{z}{t}$ axis at $z/t = 1$, and possessing a

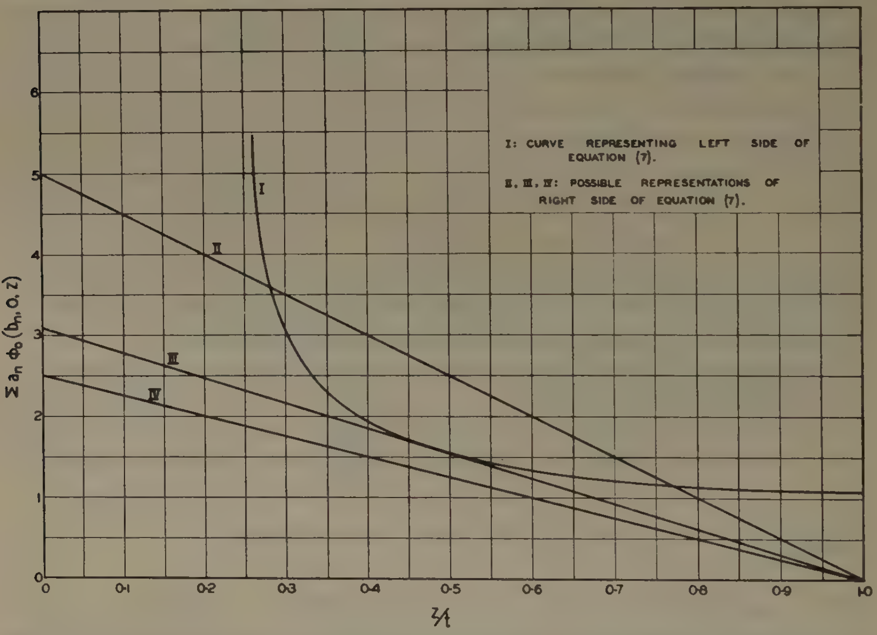

FIG. 3.—GRAPHIC SOLUTION OF EQUATION 7 TO SHOW EQUILIBRIUM CONDITIONS OF WATER CONE.

slope inversely proportional to ΔP. Several such lines are drawn in Fig. 3. Depending on the slope of the lines, their intersections with curve I, or the roots of equation 7, will be two in number, one, or none at all.

We must now examine more closely the meaning of these intersections. Analytically, they both represent the cone heights, for the corresponding physical constants of the system and the chosen ΔP, which satisfy the hydrostatic equilibrium condition, equation 1. Physically, however, the two intersections are of quite different significance. For at the higher rise of cone, $\frac{z}{t} = 0.28$, the slope of curve I exceeds that of curve II, which means that at $z = 0.28$ the gradients in the oil zone will exceed the hydrostatic gradient in the water zone. Hence, even though there could be *hydrostatic* equilibrium at $z = 0.28$, the equilibrium would be dynamically unstable against infinitesimal perturbations in the cone surface. The roots at $\frac{z}{t} = 0.28$ can therefore play no role in the physical problem. Conversely, however, the root at $\frac{z}{t} = 0.77$ gives a physically *stable* cone, as the gradient there, in the oil zone, is less than that in the water zone. If ΔP is increased the slope of the lines for the right side of equation 7 will decrease until, as with curve III, they will be tangent to curve I and then for still greater ΔP there will be no intersections with curve I, or no stable heights of cone. The point of tangency of curves II and III $\left(\frac{z}{t} = 0.48\right)$ then gives the critical and maximum cone height possible for the given r_e, r_w, t and $\Delta\gamma$.

It is evident that in the vicinity of the critical cone defined above the position of the water surface is very sensitive to small changes in pressure within the adjacent oil zone. Recalling that the analysis has been based upon a pressure distribution undisturbed by the presence of a cone, whereas there will actually be a perturbation in the pressure distribution because of the existence of the cone, it is necessary to present more conclusive evidence that stable cones cannot exist at every height up to the bottom of the well. Thus if the perturbation in the pressure distribution is such as to increase the pressure at points near the top of the cone relative to the unperturbed pressure, the tendency will be towards increased stability, with the possibility that no critical height exists, whereas, if the perturbation is the reverse the stability will be even more critical than obtained on the basis of the analysis presented and the possibility of stability at any arbitrarily large height will be definitely eliminated.

Since the determination of the exact pressure distribution in the oil zone above the cone is impossible analytically, an experimental method has been used. It consists of an electrical conduction model (described in a later section) which is analogous to the present fluid problem in all respects except that gravitational effects are not simulated and must be introduced by proper experimental procedure.

Fig. 4 shows photographs of the model representing a radial vertical sector of a sand horizon underlain by water that has coned upward beneath the well because of the pressure differential maintained between the outer radius and the partly penetrating well. In Fig. 4c the full lines in the "oil zone" show the unperturbed pressure distribution; i.e., in the absence of a cone and the dotted lines the pressure distribution within the oil zone in the presence of a stable water cone represented by the white portion of the photograph. That the shape of the cone in the figure is a good approximation to that of a real cone is shown by the fact that the intersections of the equipressure lines with the surface of the cone lie at equal intervals above the base of the cone, thus satisfying the equilibrium conditions[2] of equations 1 or 1*a*. Figures 4*d* and 4*e* show the same system with higher cones, as would be induced by increasing the total pressure drop between the well and the outer boundary. These cones are stable over their entire surface, as indicated by the

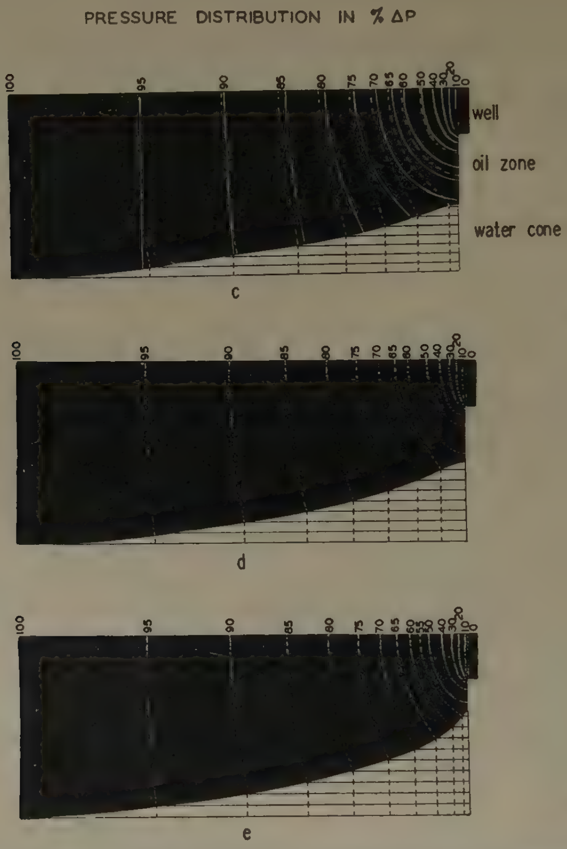

FIG. 4.—MODEL REPRESENTING RADIAL SECTOR OF SAND HORIZON UNDERLAIN BY WATER WHICH HAS CONED UPWARD BENEATH WELL. PRESSURE DISTRIBUTION IN PER CENT ΔP.

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[2] The proper shape of the nonconducting portion of the model representing the cone was necessarily obtained by trial. The sensitivity of the potential distribution measuring equipment was sufficient to locate the equipotentials more accurately than they could be marked on the surface.

equal intervals between the vertical projections of the equipressure intercepts at the cone surface.

While the numerical values of the equipressure contours are given in percentages of total pressure differential across the system, a comparison between the several models may be made in terms of relative pressures.

In Fig. 4*c*, 35 per cent of the total pressure drop ΔP_c is imposed on the cone whose height h at its intersection with that equipressure contour

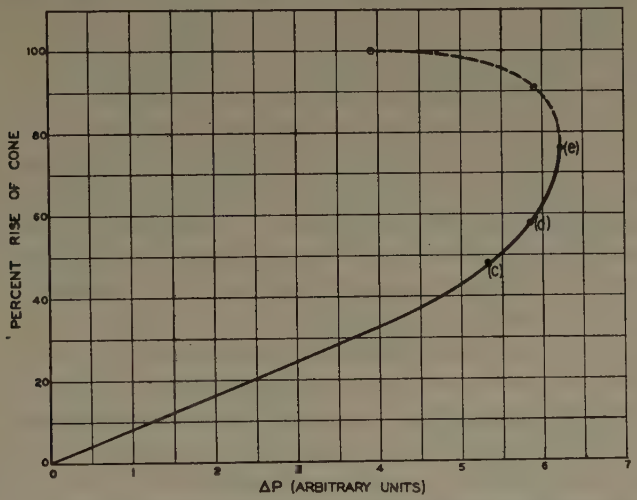

FIG. 5.—VARIATION OF CONE HEIGHT BELOW WELL WITH PRESSURE DROP ACROSS SAND, AS OBTAINED BY MEANS OF MODEL EXPERIMENTS. WELL PENETRATION 25 PER CENT.

is 1.86 arbitrary units. In the notation of the equilibrium equation 1*a*, and assuming $\gamma_w = 1$, we have:

$$0.65\Delta P_c + 1.86g = \Delta P_c;\ \Delta P_c = 5.32g$$

Similarly from Fig. 4*d*:

$$p(0,\ h) = 0.65\Delta P_d;\ h = 2.05;\ \Delta P_d = 5.86g$$

and from Fig. 4*e*:

$$p(0,\ h) = 0.55\Delta P_e;\ h = 2.80;\ \Delta P_e = 6.22g$$

Plotting these values of total pressure differential against the total height of cone as measured from the models, the curve of Fig. 5 is obtained. While only the three points *c*, *d* and *e* were observed experimentally, it is clear that stable cones will also exist under the conditions represented by the lower approximate projection of the curve. However, the question regarding the upper extension of the curve (i.e., whether stability obtains up to the bottom of the well—100 per cent rise) remains unanswered. Fig. 4*e* shows that if an attempt is made to raise the cone to the 40 per cent pressure contour the ΔP, calculated as above, will have a value somewhat less than $5.9g$. Thus the upper branch of the curve turns back as indicated by the dotted projection. Indeed, at $h = 100$ per cent it is obvious that the equilibrium equation 1*a* can be satisfied only if ΔP does not exceed the total available hydrostatic head, which in the above units is equal to 3.94 g, the upper terminal point of the curve, Fig. 5.

The results of the experiments, therefore, are to be interpreted as definitely indicating the existence of a critical cone height which, for the particular system represented by the models, is in the vicinity of 76 per cent of the total distance between the bottom of the well and the normal water level. Below this height *all* cones are possible and above it, although the hydrostatic equilibrium conditions can be satisfied, the simultaneous existence of dynamical equilibrium previously mentioned is not possible and stable cones cannot exist. Thus the conclusions derived from the analytical curves of Fig. 3 are verified by experimental methods, which involve no assumptions as to the effect of the cone on the pressure distribution. In fact, the experiments show that the cone is actually somewhat more critical than indicated analytically.

Returning now to the further development of the analytical treatment, the behavior of the cones in systems of practical interest will be considered. The procedure consists in observing the slopes of the lines as of curve II in Fig. 3 giving a certain intersection with potential curves as curve I these intersections representing cone heights z/t. The slope m of these lines is clearly given by:

$$m = -\frac{B}{\Delta P} = \frac{-gt\Delta\gamma\left(\Phi_e - \frac{4}{t}\Sigma a_n b_n \log \frac{4t}{r_e}\right)}{\Delta P}$$

Hence, knowing m and the other constants of the system, ΔP can be computed. These may then be plotted against the corresponding z/t. Such curves are given in Figs. 6 and 7 and correspond to the following constants:

$\Delta\gamma = \gamma_w - \gamma_0 = 0.3$ gram per cubic centimeter.
$g = 980$ and is equivalent to 0.0097 atmospheres for unit density.
$t = 125$ ft; r_w = well radius = ¼ ft.
r_e = formation boundary = 500 ft.
Nonpenetrating well: $\Phi_e = 2002.3$; $\Sigma a_n b_n = 250$.
25 per cent penetration: $\Phi_e = 11.25$; $\Sigma a_n b_n = 33.25$.
50 per cent penetration: $\Phi_e = 13.28$; $\Sigma a_n b_n = 67.00$.

The fact that the pressure drops required to raise the cones are so small, as appears from Fig. 6, is not surprising when it is noted that a water column of height equal to one-half of the sand thickness of 125 ft. has a head of less than two atmospheres. Furthermore, since the ΔP in

Figs. 6 and 7 are pressure drops as measured at the top of the sand, the pressure drops in the oil zone available to lift the water are the ΔP of Figs. 6 and 7 plus the hydrostatic head of oil between the bottom of the well and the bottom of the oil horizon. On the other hand, the relatively large values of ΔP required to raise the cone in the case of the nonpenetrating well are due entirely to the great concentration of the pressure gradients near the well when the latter only taps the sand. In fact, the

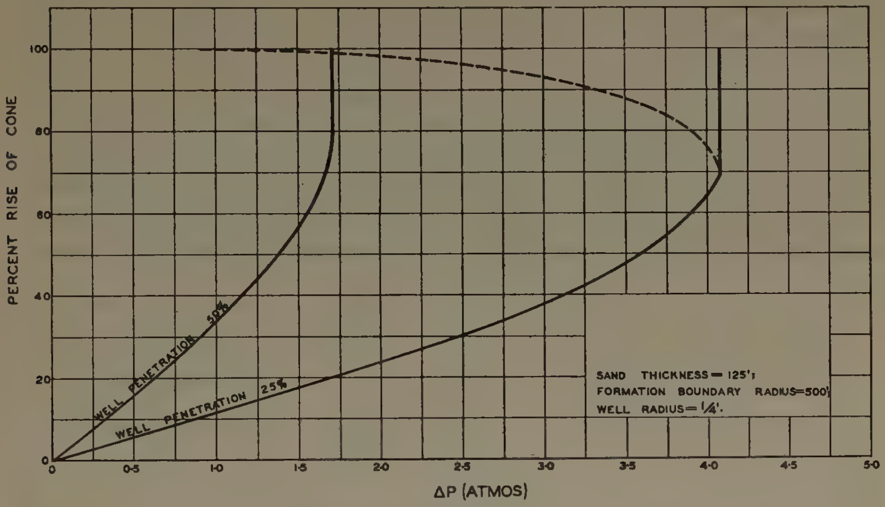

FIG. 6.—VARIATION OF CONE HEIGHT BELOW WELL WITH PRESSURE DROP ΔP ACROSS SAND.

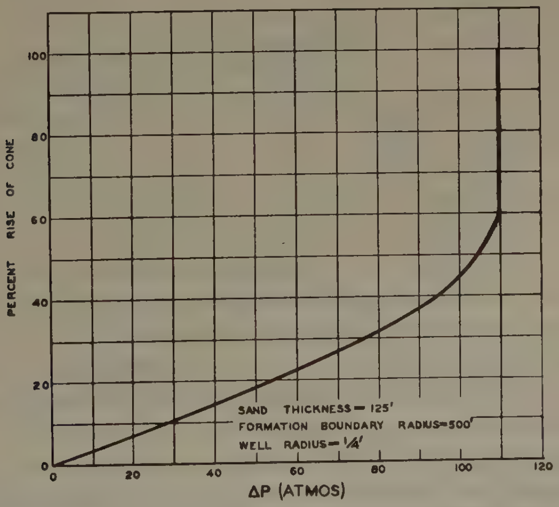

FIG. 7.—VARIATION OF CONE HEIGHT BELOW NONPENETRATING WELL, WITH PRESSURE DROP ΔP ACROSS SAND.

pressure gradients near the well vary inversely as the square of the distance from the well. Hence, it may be that more than 100 atm. of the total pressure drop of 107 atm. (for a cone rise of 54 per cent) is lost within 5 ft. of the well and only a small fraction of it is effective in raising the water in the cone.

The vertical sections of the curves simply indicate the fact that beyond the critical heights corresponding to the points of tangency as of curves I and III, Fig. 3, physically stable cones cannot exist. The dotted portion of the curve for 25 per cent penetration, Fig. 6, represents the upper intersection as for curves I and II, Fig. 3, and is to be compared with the experimental curve, Fig. 5. The similarity of the two is evident, though it should be mentioned that the discontinuity in the analytical curve at the critical height is caused by the neglect of the perturbation in pressure distribution due to the presence of the cone. The effect of this perturbation is to eliminate the discontinuity and to increase the sensitivity of the system to slight changes in pressure differential.

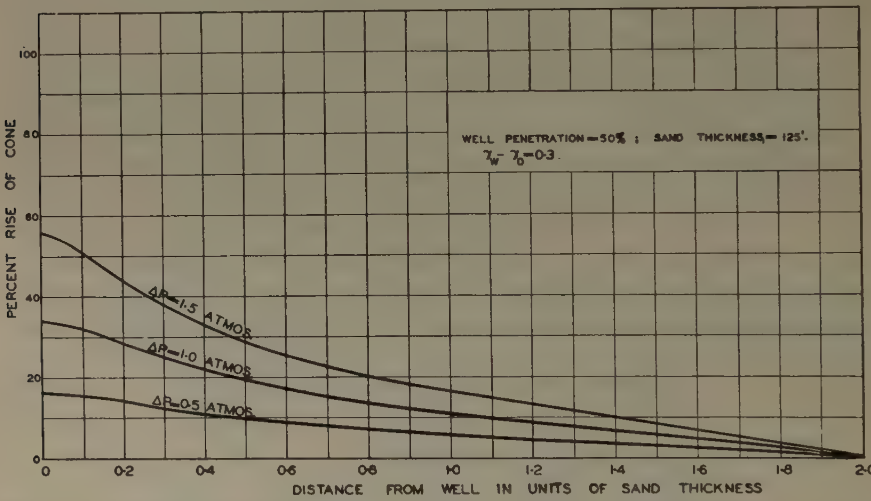

FIG. 8.—CROSS-SECTIONAL SHAPE OF CONES FOR VARIOUS PRESSURE DROPS (ΔP).

All of the above discussion with regard to the height of the cone has referred to its value along the central axis of the sand, that is, in the region immediately below the well. However, it should be clear that the computations can be carried through in exactly the same manner for any distance out from the well provided only that the curve I in Fig. 3 be appropriately changed and made to refer to the vertical potential distribution at the chosen distance from the well. If this is done for a number of such radial positions from the well, a graphic representation of the shape of the cone will be obtained by plotting the roots of equation 7 derived as indicated above. The results of such computations for a

125-ft. sand when the well penetration is 50 per cent and for various pressure differentials over the sand are presented in Fig. 8. The actual shape of the cones, of course, will be obtained by rotating the curves of Fig. 8 around the vertical axis. Although from the nature of the calculation these curves cannot be accurate in detail, they do have the general shape that would be expected of the streamline curves representing the cone surfaces.

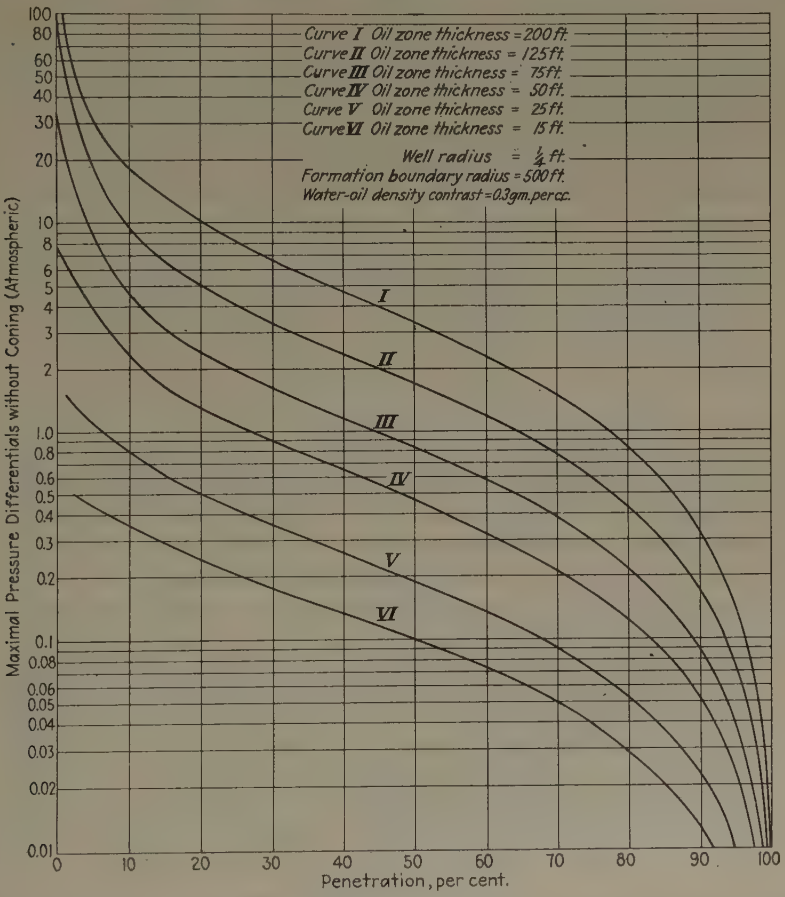

FIG. 9.—MAXIMAL PRESSURE DIFFERENTIALS (RESEROVIR PRESSURE-BOTTOM-HOLE PRESSURE) WITHOUT CONING AS A FUNCTION OF WELL PENETRATION FOR VARIOUS OIL-ZONE THICKNESSES.

The values of the critical pressure differentials required to bring the cones into the well, and obtained by solving equation 7, as outlined above, are given in Fig. 9. As already noted, the critical pressure differential increases very rapidly, especially for the thicker sands, as the well penetration becomes small. Similarly, it falls steeply to infinitesimal values as the well penetration approaches 100 per cent and the bottom of the well is set near the water level. Finally the critical pressure differential not only decreases with decreasing sand thickness, as should be expected, but the variation with the sand thickness becomes increasingly pronounced as the thickness decreases.

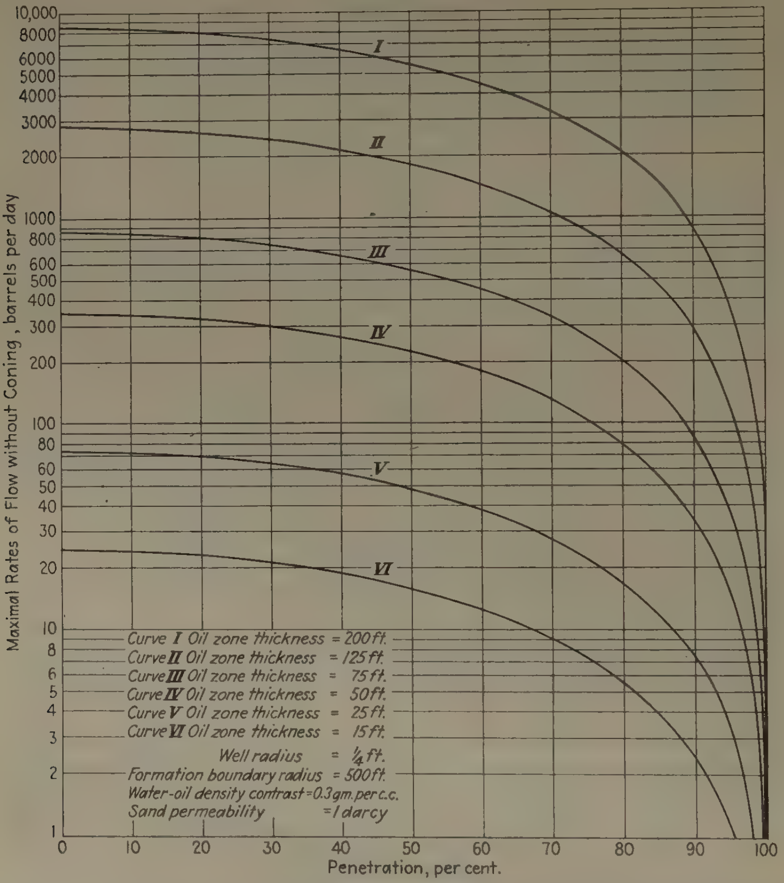

FIG. 10.—MAXIMAL RATES OF FLOW WITHOUT CONING AS FUNCTION OF WELL PENETRATION FOR VARIOUS OIL-ZONE THICKNESSES.

Although, from a physical point of view, the pressure differentials and gradients are the controlling factors determining the stability of the water cone, the relation of the rate of oil production to the entry of the water into the well is perhaps of most interest from a practical point of view. To find the production rates corresponding to the ΔP of Fig. 9 it is only necessary to apply equation 6, which for the present purpose may be rewritten as:

$$Q = \frac{4\pi k \Delta P \Sigma a_n b_n}{\mu\left\{\Phi_e - \frac{4}{t}\Sigma a_n b_n \log \frac{4t}{r_e}\right\}} \qquad [9]$$

The critical or maximal production rates obtained in the above manner are plotted in Fig. 10. Perhaps the most interesting feature of these curves is the fact that the nonpenetrating wells will permit the maximal production rates without the cone entering the well. Of course, the fact that the bottom of a nonpenetrating well is at a greater distance from the water horizon than the bottom of a partially penetrating well, would naturally tend to make it more favorable for the suppression of the cone, and indeed Fig. 9 does show that the critical pressure differentials are maximal for the nonpenetrating wells. On the other hand, the very high resistance of the nonpenetrating well system might be expected to more than counterbalance the effect of the large separation between the bottom of the well and the water level, so as to give rise to an optimum nonvanishing penetration at which the critical production rate is a maximum with respect to both smaller and larger penetrations. The curves of Fig. 10 show, however, that the distance of the well bottom from the water level is the most significant factor, although it is to be noted that the curves are quite flat for the small penetrations and for practical purposes wells with penetrations as high as 15 to 20 per cent will give practically as high water-free production rates as those of extremely small penetrations. This is indeed a fortunate circumstance, for thus it is possible to obtain in practice the optimum operating conditions without the necessity of attempting to satisfy the almost impractical condition of "nonpenetration" in an actual well.

The practical significance of the above analysis is that it shows that considerable penetrations into an oil sand should be avoided if it is known that the lower portion contains water. It further shows that if at a certain finite penetration and a given production rate, water-coning is already taking place, one may reasonably attempt to correct the situation by plugging back the hole to effectively reduce the penetration. This implies the fact that coning, once started in an oil sand, is not necessarily a permanent accompaniment of the production, since the essential reasons for the persistence of the coning are that: (1) the pressure drop between the reservoir boundary and points below the bottom of the well exceed the hydrostatic head of the corresponding water column and (2) that the dynamic pressure gradients in the system exceed the static gradient caused by the density difference between the oil and water. Hence if the well is plugged back or the production rate is "pinched down" so that the total pressure drop and dynamic gradients become insufficient to overcome the hydrostatic head and gravity gradient, the water cone can only fall back towards the bottom of the formation. The time for these transitions to take place is a rather difficult quantity to estimate but it certainly seems that it should be measurable in terms of a relatively small number of days, if not hours. Thus it appears that at least by the process of controlling the back-pressure on a well one should be able to control with a fair degree of arbitrariness either the rate of water entry into the well or to stabilize the oil production with the water lying statically below the oil horizon.

Suppression of Water-coning by Shale Lenses

While field experience, as a whole, confirms the conclusions developed here concerning the suppression of water coning by decreasing the penetration of a well, it is often observed that the magnitude of the effects are much larger than would be expected from Figs. 9 and 10. Thus, cases have been observed where plugging back only 2 or 3 ft. has sufficed to eliminate almost completely the water from wells that previously had been producing with rather high water-oil ratios. As an example may be cited a well in East Texas, in which a 20 per cent water content was changed into clean oil flow by simply plugging back 2 ft. of its original penetration of 7 ft. It is clear that if the sand were homogeneous, as has been assumed in the theory given here, the change in total well penetration from approximately 16 to 11 per cent would have but a very small effect in suppressing the water cone, so that the observed effect must be attributed to an inhomogeneity in the sand conditions. In fact, the log of the above well shows a tight zone 2 ft. thick beginning 4 ft. below the top of the pay and the well was plugged back to this zone.

That an extended shale streak lying at the bottom of a well would inhibit bottom water from coming into a well is obvious, of course. In most sands, however, many shale streaks occur as small broken lenses embedded in the main sand body, and the question arises as to the effectiveness of plugging back to such lenses of limited extent. Although it would be quite hopeless to attempt to derive an analytical solution to the problem involved, the question proposed may be answered in a very simple manner with the aid of an electrical model of the flow system. The model, similar to that used in obtaining Fig. 4, is based upon the strict equivalence of the current flow in a continuous conductor and the liquid flow in a porous medium of the same geometry and corresponding boundary conditions[3]. The model used here was a radial sector of pressed carbon, at the broad end of which was soldered a metal plate to give the effect of a uniform reservoir pressure, and at the vertex of which was soldered a thin copper rod representing the partly penetrating well, at the uniform pressure $p_w = 0$. The equipressure contours for a 50 per cent well penetration in a homogeneous sand are indicated in Figs. 11 and 12 as the solid lines where the external pressure has been taken for convenience equal to 100. The permeable shale lenses were then introduced by simply cutting narrow slots below the well bottom, in one case with a radius equal to 11.3 per cent of the sand thickness and in another case with a radius 20.6 per cent of the sand thickness. The new pressure distributions are shown as the dotted curves.

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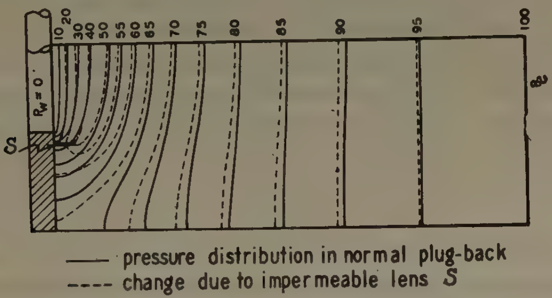
[3] The effect of gravity in systems having free surfaces or two fluid interfaces has no electrical analogy, but this difference will affect only the quantitative details of the problem under consideration. For a discussion of other experimental models that may be used in the study of fluid flow through porous media, see R. D. Wyckoff and H. G. Botset: *Physics* (September, 1934) **5**.


10
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50
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70
75
80
85
90
95
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$p_w = 0$
S
p_e
—— pressure distribution in normal plug-back
---- change due to impermeable lens S

FIG. 11

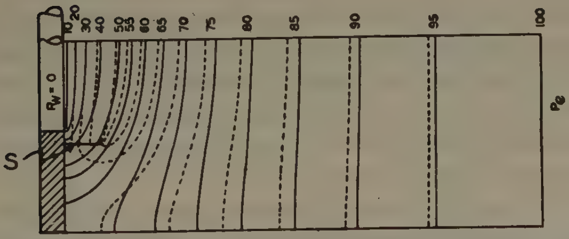

FIG. 12

FIGS. 11 AND 12.—EQUIPRESSURE CONTOURS FOR 50 PER CENT WELL PENETRATION IN HOMOGENEOUS SAND (SOLID LINES) AND PRESSURE DISTRIBUTIONS AFTER INTRODUCTION OF PERMEABLE SHALE LENSES (DOTTED LINES).

Although a quantitative application of the changes in pressure distributions caused by the slots or shale lenses will not be attempted, the qualitative implications are quite definite and unambiguous. For it is clear from Figs. 11 and 12 that in the presence of the impermeable lens the pressure gradients are concentrated and increased in the upper part of the sand and near the edge of the lens while they are diminished at distant points from the well and in the region below the lens. The particular point of interest, however, is the fact that the presence of the lens very markedly increases the pressure in the region below the lens, where the water would tend to rise. Thus, in the smaller lens of Fig. 11 the point at the bottom of the lens terminating the 55 per cent pressure contour originally lay on the 40 per cent contour in the homogeneous sand; in the lens of Fig. 12 the same point on the original 40 per cent contour would terminate the 65 per cent contour in the presence of the lens. As the height of rise of the cone at a given point is essentially proportional to the pressure differential between that point and the effective sand-reservoir boundary, it is clear that the two lenses corresponding to Figs. 11 and 12 would lower the coning tendency to values of the order of 75 and 58 per cent of what they would be in a homogeneous sand. Such effects might well correspond to a change from a 20 per cent water-oil ratio to the production of pipe line oil.

Thus it appears that the apparently anomalous success in the elimination of water-coning by plugging back a well may be explained on the basis of the same physical principles as the more commonly observed manifestations of the phenomenon. Furthermore, it seems that perhaps the most effective means of eliminating bottom water in a well penetrating a homogeneous sand is to plug the well back to one of the tighter lenses even though such lenses may be of very limited lateral dimensions.

SUMMARY

The purpose of this discussion has been to present the fundamental physical principles underlying the behavior of the water-oil interface when oil is produced from a well only partly penetrating the oil zone while the water remains in static equilibrium in the lower portion of the pay horizon. It is clear that similar principles are involved when considering the regional advance of edge water as it encroaches the oil zone along the sloping flanks of a structure, the density contrast between the oil and water, the slope of the strata, and the regional pressure distribution, being the controlling factors in such cases.

The points of practical interest derived from the analysis of the specific problem of water-coning as referred to individual wells are:

1. The critical nature of the water cone is shown by the accelerated rise of the cone as the oil-production rate is increased with the final attainment of instability when it has reached a point some 50 to 75 per cent of the height to the bottom of the well. At the upper portion of the region of stability the cone is shown to be extremely sensitive to small changes in pressure differential; i.e., oil production rate.
2. It is impossible to eliminate bottom water when producing from a thin oil zone unless the production rate of the well is reduced to uneconomically low values.
3. For any thickness of oil zone a well of minimum penetration permits the maximum rate of water-free oil production, but up to as high as 15 or 20 per cent penetration the variation in permissible rate is too small to warrant consideration. Fortunately this means that the exact value of the penetration is of little moment provided it is reasonably small.
4. It is futile to plug back a well that already has a small penetration unless it can be plugged back to an impermeable lens. Even if this lens is

of small areal extent it will have a pronounced effect in suppressing the cone.

5. Because of the critical nature of the cone it appears that the most favorable method of control is to pinch in drastically or completely shut in the well and then increase the production to its maximum water-free rate rather than to slowly pinch back on the rate. The reason for this procedure is the probable existence of a marked "hysteresis" in the curve of pressure differential vs. cone height, especially in the critical region, so that this region should always be approached by a rising cone.

6. From the nature of the cone height vs. pressure differential curve it may be shown that for a given *average* pressure differential or production rate a steadily flowing well will induce a lower cone height than one in which the flow is intermittent. Thus in the presence of bottom water, a well that is heading, or particularly one that is being produced by swabbing, may show considerable amounts of water, which would be entirely eliminated under steady flow conditions at the same or even a higher production rate[4].

The water-coning problem is the exact analog of "gas-coning." Thus it is evident that if gas has accumulated in the upper portion of the pay horizon and this gas zone has been packed off so that the sand face is open *only* in the lower portion of the oil pay, the physical set-up is identical to that of the water problem discussed here, except that the system is inverted. Furthermore, since the density contrast between the oil and gas is considerably greater than between water and oil, the possibility of controlling the gas cone is correspondingly more favorable, but otherwise its response to variations in oil-production rate, to position of the open sand face *below* the *bottom* of the gas zone, i.e. "penetration," and to the other variables, will be identical. However, careful consideration must be given to the mechanical set-up in the well if the analogy is to be correct.

Finally, we wish to emphasize that this discussion is confined to the consideration of a single producing horizon and does not include systems in which the several fluids are present in discrete unconnected strata. Furthermore, although homogeneity of the sand is tacitly assumed in the analysis, any anisotropy in permeability is likely to be such that the vertical permeability is the lower, and suppression of the cone will be correspondingly easier.

ACKNOWLEDGMENTS

The authors are indebted to Messrs. D. W. Reed and M. W. Meres for assistance in some of the experimental work and preparation of the figures and to Dr. P. D. Foote for permission to publish this paper.

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[4] H. C. Miller: Function of Natural Gas in the Production of Oil, pt. 1, 79. Recovery of Oil by Air and Gas Lift, 185. Whealton & Townsend, Inc.

DISCUSSION

(L. A. Ogden presiding)

T: V. Moore,* Houston, Texas.—These authors have presented an analysis of water-coning that is of greater practical value than we realize. They had to assume permeability of the sand. These cones are stable and their position depends on the different hydrostatic heads of the water and the hydrostatic heads of the oil, and not on the permeability of the sand. The analysis is still applicable. It seems that in order to plug off water completely from the well, it is necessary to plug both water and a portion of the oil zone.

R. D. Wyckoff.—An application of the theory that may be of interest pertains to acid treatment. Assuming that the acid enters the water zone as well as the oil zone and is equally effective in increasing the permeability of both zones, offhand one would expect no change in water-oil ratio. However, since the water-coning is dependent upon pressure differential alone, and for a given differential the production rate is proportional to the permeability, the theory indicates that increasing the permeability of both zones will result in a decreased water-oil ratio. There is definite field evidence to show that on the average acid treatment does result in a lower water-oil ratio in cases of bottom water to which the coning theory should apply.

W. L. Horner,† Bradford, Pa.—In using a sand model I had to use a river sand finer than Ottawa sand to get a good cone, at constant pressure.

Member.—You say that in thin sand plugging back does not eliminate water?

R. D. Wyckoff.—It looks as though in thin sands one would have to accept the water as inevitable since the water cone could be made stable only at excessively low production rates. A thick oil zone permits the establishment of a reasonably high pressure differential and proportionately high production rates without necessarily exceeding the limiting differential for the critical cone.

H. H. Wright,‡ Tulsa, Okla.—Irrespective of the configuration of the water-cone surface, only one condition must be satisfied analytically for stability and equilibrium: the resultant of all forces acting on any element of the cone surface shall equal zero, and the direction of the resultant shall be perpendicular to the surface of the cone. More exactly, the direction of the resultant shall approach that of perpendicularity as the condition of static equilibrium is approached.

The difficulty of evaluating the various forces is evident, but there is one element of the cone surface for which analysis is simple, provided one is willing to forego the determination of values for this point at its maximum stable height. The sensitive or "critical" nature of the cone along the projected well axis at heights in close proximity to the well is evident from the rapid increase of the pressure gradient in the oil zone along the surface of the cone. The sensitive nature of the part of the cone surface immediately below the well at heights close to the well perhaps can be visualized more clearly from the rough statement that the apex of the cone becomes more acute as the well is approached, and the necessary condition for static equilibrium, that the resultant of all forces acting on a surface element shall equal zero, and shall act in a direction approaching that perpendicular to the static surface as equilibrium is approached, becomes increasingly difficult of fulfillment.

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† Charge of Production Research Laboratory, Forest Oil Corporation.

‡ Petroleum Engineer, Gypsy Oil Co.

I am interested in another phase of the paper; that pertaining to the effect of impermeable barriers of limited areal extent. Several years ago I investigated a well in the Seminole field which had a penetration of 11 ft. in the Wilcox sand, and which had had a very rapid decline to a settled production of about 20 bbl. of oil daily. This well had been drilled 0.5 ft. in shale at its bottom. It was decided to drill the well deeper, and after the shale break in which the well was bottomed originally had been penetrated, production was increased to something over 500 bbl. of oil daily. The effect of the impermeable barrier on production is very well illustrated by this case.

R. D. Wyckoff (written discussion).—It is interesting to note that if the permeability of the sand above the shale member mentioned by Mr. Wright had been about the same as in the lower zone a large change in production rate would have been observed only if the shale break was of large areal dimensions. In fact, if the original 11-ft. penetration represented 20 per cent penetration of a homogeneous sand body with the shale break of unlimited extent, penetration of the entire sand body below the shale would have increased the production rate to 100 bbl. per day. The observed increase to 500 bbl. per day is evidence that the upper sand has a low permeability compared with the deeper zone. If, however, the shale break in an otherwise homogeneous sand had been of small areal extent the production rate after penetrating the lower zone would have been of the order of 50 barrels.

This is mentioned merely to point out that plugging back to a small tight lens to suppress water does not necessarily involve an excessive sacrifice in production rate, and that in the example cited by Mr. Wright the very large change in capacity of the well was due primarily to low permeability of the upper oil zone. It is also evident that the economic gain in back-plugging depends largely upon the magnitude of restriction imposed on the well. Thus, if the allowable production rate represents but a small fraction of its potential, back-plugging to eliminate water may not necessarily involve an actual decrease in the daily production rate.

K. B. Nowels,* Bradford, Pa. (written discussion).—This study of water-coning is timely and valuable. The authors' findings and conclusions are substantiated by some work done by the U. S. Bureau of Mines engineers in the Wortham and Powell fields of Texas[5]. In those fields the bottom-hole stage plugging was done in order to exclude both bottom water and the water that gained entrance to some of the producing wells through coning.

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* Chief Petroleum Engineer, Forest Oil Corporation.

[5] H. B. Hill and C. E. Sutton: Production and Development Problems in the Powell Oil Field, Navarro County, Tex. U. S. Bur. Mines *Bull.* 284 (1928).

H. B. Hill and C. E. Sutton: Petroleum Engineering in Wortham Oil Fields, Limestone and Free Stone Counties, Tex.

Variations in Reservoir Pressure in the East Texas Field

BY RALPH J. SCHILTHUIS,* MEMBER A.I.M.E. AND WILLIAM HURST*

(Tulsa Meeting, October, 1934)

THE nature of the forces that are important in producing the oil in the East Texas field and the manner in which these forces are affected by the rate of production have always been problems of outstanding interest. These questions are of great interest to the industry as a whole on account of the economic importance of the East Texas field and to the engineers in particular on account of the unique character and behavior of the field. Subsurface pressure data throughout the field have been collected systematically, so that a quite complete history of the reservoir pressures has been kept as the field has been developed and produced. Subsurface samples of the oil and gas have been taken and these have been examined to obtain data on the physical properties of the reservoir fluids under the actual conditions of temperature and pressure. All of these data have been valuable because they have afforded the basis for a careful study of the means by which the oil is produced. It is the purpose of this discussion first to point out several of the important facts revealed by the data mentioned and then to describe studies that have been made concerning the interpretation of these facts.

RESERVOIR PRESSURE DATA AND PROPERTIES OF OIL

The reservoir pressure data on the East Texas field have shown conclusively that the pressures are readily affected by changes in the rate at which the field is produced. This can well be seen in Fig. 1, where the average reservoir pressures obtained from time to time are plotted with the daily production rates and the cumulative production of the field. It is noted that the average reservoir pressure has declined irregularly, depending upon the rate of production, from the estimated original value of 1625 lb. per sq. in. to the value of 1228 lb. per sq. in. observed for Aug. 11, 1934. The decline in pressure has been more rapid at the higher rates of production than at the lower rates. In contrast, the average reservoir pressure has increased, on several occasions, upon reduction of the withdrawal rate from a high value to a lower value.

The reservoir pressure data have also shown that a definite gradient in pressure has existed across the field from west to east since the begin-

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ning of production. The pressures are highest on the west boundary of the field, decreasing gradually to the east edge. The magnitude of this pressure gradient is also influenced by the rate of production, the difference in pressure from west to east becoming greater as the production rate is increased.

Physical Properties of Reservoir Oil.—Lindsly[1*], in his investigations on the physical properties of the reservoir oil in the East Texas field, demonstrated the following facts:

1. The reservoir oil is undersaturated with gas, the saturation pressure being 740 lb. per sq. in. gage. This pressure, which corresponds to the point where gas first starts to escape solution, is several hundred pounds per square inch less than the lowest average pressure that has ever been observed in the East Texas field.

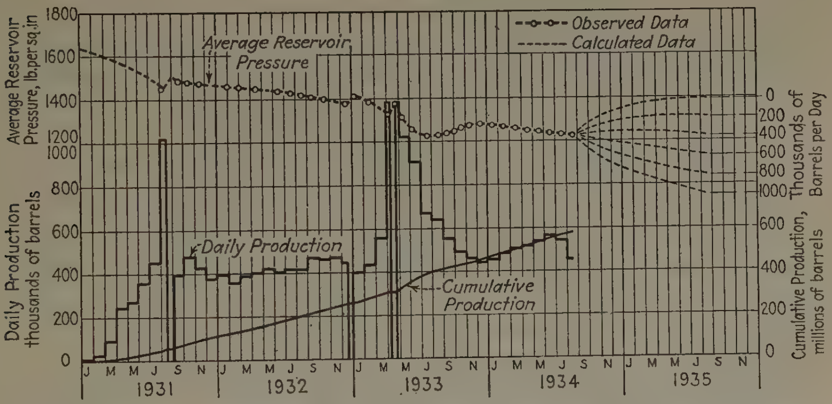

FIG. 1.—RESERVOIR PRESSURE AND PRODUCTION DATA, OBSERVED AND CALCULATED, EAST TEXAS FIELD.

2. Above the saturation pressure of 740 lb. per sq. in., the reservoir oil has a liquid expansibility of 0.098 per cent for each reduction of 100 lb. per sq. in. in the pressure upon the liquid.

3. The reservoir oil, in being produced to the surface, shrinks, or suffers a net loss in volume of about 20 per cent. The shrinkage is due mainly to liberation of dissolved gas upon reduction in pressure from the saturation pressure to one atmosphere. A small part of the contraction is accounted for, however, by reduction in temperature from the reservoir temperature of 146° F. to the temperature at the surface.

These physical properties of the East Texas reservoir oil have also been investigated and checked, within reasonable limits, in the laboratories of the Humble Oil & Refining Company.

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[*] References are at the end of the paper.

Interpretation of Data

In the foregoing, the most important information concerning the behavior of the reservoir pressures and the physical properties of the reservoir oil in the East Texas field have been reviewed.

A little reflection on the fact that the reservoir oil is undersaturated will make it evident that the oil body must be acted upon by some extraneous force, which maintains the pressure in excess of the saturation pressure of the oil. If there were no such force, the reservoir pressures would have fallen, rapidly, below 740 lb. per sq. in. Regarding the nature of the extraneous force, it has been suggested[2] that the weight and compressibility of the overlying sediments and rocks supplies the excess pressure. J. O. Lewis[3] has shown that this suggestion is untenable. Both the original and current average reservoir pressures can be explained by water pressure or a water drive acting upon the oil body. The contention that a water drive does act upon the field is compatible with both geological information and the data on reservoir pressures and the physical properties of the reservoir fluids.

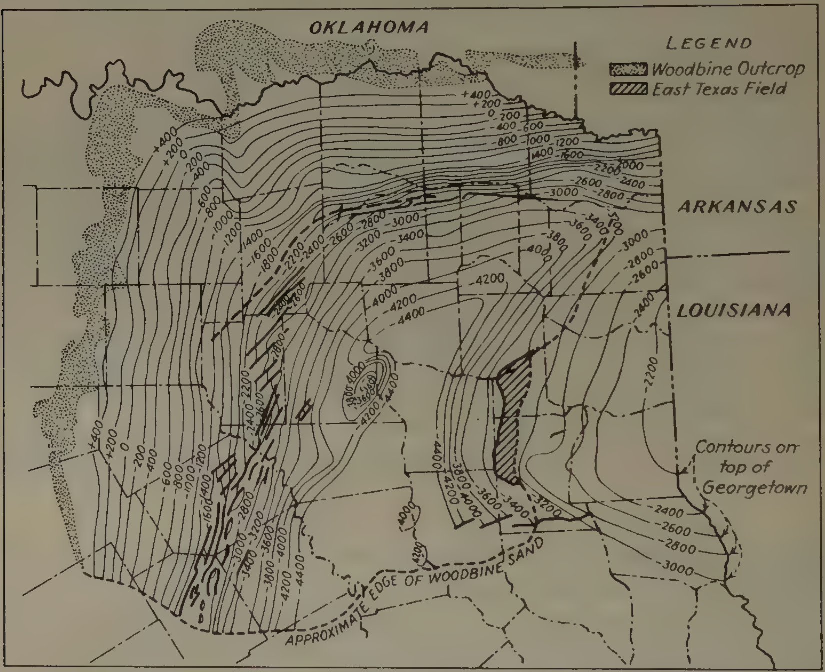

Fig. 2.—Structure contours on top of Woodbine sand, northeast, Texas.

Fig. 2 is a map of the East Texas area showing the relation between the Woodbine formation and the East Texas oil field. The Woodbine formation outcrops in a belt extending northward from McLennan

County, Texas, to the Red River valley and then eastward to the Oklahoma-Arkansas border. The formation dips southeastwardly, pinching out to the south, and finally rises gradually to the east to pinch out against the Sabine uplift and make the reservoir in which water has trapped oil to form the East Texas oil field. The field occupies only a small part of the vast Woodbine formation, being located at the approximate center of the Woodbine's eastern boundary. There is sufficient evidence to show that the Woodbine sand is continuous from its outcrop to the East Texas field and is filled with water. The head of water equal in height to the difference between the surface elevation of the Woodbine's outcrop and the subsea depth of the oil reservoir would exert a static pressure in close agreement with original reservoir pressure. The fact that since production began a gradient in pressure has existed across the field from west to east further substantiates the contention that the field is under water drive and indicates that the water is tending to push the oil body eastward in the reservoir.

East Texas Water Drive

Nature of Water Drive.—As soon as production started, the reservoir pressure began to decline below the original value about the wells produced. This lowering of the pressure allowed the oil in the vicinity of the wells to expand and fill the space formerly occupied by the oil removed. As production continued, the lowering of the pressure spread rapidly to the more remote parts of the field on account of the limited expansive power of the remaining undersaturated reservoir oil. It was observed, however, that as more oil was produced the pressures did not decline as rapidly as would be consistent with the expansibility of the remaining undersaturated oil and the quantities of oil removed. This condition indicated that the pressure differential set up between the higher pressure in the water sand to the west and the lowered pressure in the oil reservoir itself had caused water to encroach into the field. Such encroachment of water moved oil ahead of it toward the producing wells, the oil so moved filling the space formerly occupied by oil produced and thus retarding the decline in pressure. There is no doubt that water did encroach into the oil reservoir, for, if the water had not moved in, the expansibility of the undersaturated remaining oil would permit less than 70,000,000 bbl. of production before the reservoir pressure would have been reduced to the saturation pressure of the oil; namely, 740 lb. per sq. in. The fact that much larger quantities of oil have been produced without causing such a large decline in pressure proves that the water drive is effective. The data indicate that about 5 per cent of the vacated space has been filled by expansion of oil left in the reservoir, while the remaining 95 per cent has been filled by intrusion of water. As the oil shrinks by 20 per cent upon being produced to the surface, about

1.18 bbl. of water moves into the field for each barrel of oil measured in the stock tanks.

Originally, the approximate western half of the East Texas field was underlain by water, the water level being at 3320 ft. subsea. It is calculated that to make it possible for the water to have encroached to occupy its share of the space left vacant by the total oil produced up to Aug. 1, 1934, the water level would necessarily have had to rise 10.0 ft., assuming that the sand flooded with water still retains 25 per cent of its original store of oil and that the water rose absolutely uniformly. There are data to indicate that the water level has not risen to this extent on the western or water edge of the field. It should be pointed out, however, that these data are undoubtedly misleading. As water underlies the western half of the field and as the greater portion of the total oil produced has been taken from the central portion of the field, the water has, in all probability, risen much higher toward the middle of the field than on the western edge. This uneven rise of the water level could easily have occurred without being detected because the oil section becomes thicker toward the longitudinal center of the field and nearly all wells penetrate only two-thirds of the distance between the top of the sand and the water level. As evidence to support this reasoning, there are a number of normal depth wells, slightly to the east of the field's longitudinal center, making water. The bottoms of these wells are as much as 10 to 70 ft. above the original water table, indicating that the water level certainly could have risen enough, in an uneven manner, to agree with the total water encroachment required to fill all the space formerly occupied by the oil that has been produced.

Mechanism of Water Drive by Expansibility of Water.—There are but two methods by which water may move into the East Texas reservoir as oil is produced. The first possibility is that water enters the Woodbine formation at its outcrop and flows through the entire sand body to the oil field. The second possibility is that the flow of water is supplied by virtue of the expansive power of the water contained in the Woodbine sand. Consideration of the first method mentioned has shown that the flow of water through the sand, over the great distance between the outcrop and the oil reservoir, would entail such great friction loss and hence such large pressure drops that the water could not be supplied at the required rate under the existing pressure in the East Texas field. Concerning the second possible method, it would probably be concluded at first thought that the effect of the slight expansibility of water would be negligible. However, when the expansion of the tremendous quantities of water contained in the vast expanse of Woodbine sand is considered, relative to the quantities of water moving into the East Texas field, it is realized that the effect is important and must certainly be taken into account. The Woodbine sand is estimated to contain roughly four trillion barrels of water. It is estimated that, if the pressure on such an enormous quantity of water were lowered by only 50 lb. per sq. in., it would expand and supply enough excess water to fill the space vacated by all of the oil produced from the East Texas field to date. This example is given only to illustrate the magnitude of the amount of excess water that can be supplied by expansion of so large a body of water as is contained in the Woodbine sand. It is not at all meant to imply that the pressure is actually lowered over the entire body of water by a constant amount.

The mechanism by which water flows into the East Texas field, on account of its expansibility, is as follows: When production first started, the pressure in the reservoir and on the water adjacent to the oil body on the west was lowered. This allowed the water to expand and drive oil eastward to fill space vacated by oil produced. As production has continued, the pressures have been progressively lowered and the water has been caused to flow toward the field from greater and greater distances out in the Woodbine sand. This type of flow is essentially the same as that by which oil and gas flow to a well bore[4,5] from the surrounding formation when the pressure at the well is lowered.

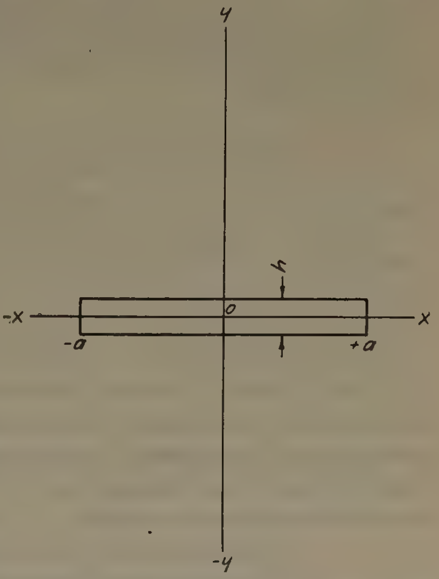

FIG. 3.—REPRESENTATION OF EAST TEXAS FIELD LOCATED IN A WATER-FILLED SAND RESERVOIR OF INFINITE EXTENT.

MATHEMATICAL ANALYSIS OF EAST TEXAS WATER DRIVE

In order to evaluate quantitatively the importance of the water drive on the East Texas field, a mathematical analysis of the described mechanism or type of flow by which water moves into the reservoir has been made by William Hurst. To develop the analysis, it was necessary to make certain assumptions, as follows:

1. The permeability, porosity, and thickness of the Woodbine sand are uniform and the formation is horizontal throughout that portion of the sand influenced by production from the field.
2. The velocity of fluid flow at any point is directly proportional to the pressure drop per unit length along the path of flow.
3. The fluids expand as pressure is lowered, the volume of the fluids increasing a certain definite percentage for each pound per square inch decrease in pressure.

With the foregoing assumptions, the analysis was based upon a material balance of the fluids flowing through a very small element of the sand formation toward the East Texas field, which is represented in Fig. 3 as the rectangle of length $2a$ and width h located at the origin of rectangular coordinates in an infinitely large water-filled sand reservoir. The material balance is expressed by the differential equation,*

$$\left[\frac{\partial^2 \rho}{\partial x^2} + \frac{\partial^2 \rho}{\partial y^2}\right]\frac{K}{\phi c} = \frac{\partial \rho}{\partial \theta}$$

The general solution of this equation for the problem of the East Texas water drive is[6]:

$$\rho = \frac{1}{4\pi\alpha^2\theta}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x', y')e^{-\frac{(x-x')^2+(y-y')^2}{4\alpha^2\theta}}dx'dy'$$

The particular solution, for the East Texas problem, is:

$$0.422\frac{HK}{c}[1 - e^{-144c(P_R-P_F)}] =$$

$$\int_{\theta_1}^{0} q_F(\theta')d\left\{\log_{10}\left[\frac{\alpha^2(\theta - \theta')}{a^2}\right]\right\}\int_0^1 e^{-\frac{(x'a)^2}{4\alpha^2(\theta-\theta')}}dx' + 1.54q_F(\theta)\sqrt{\frac{\alpha^2(\theta - \theta_1)}{a^2}}$$

The final equation expresses the variations in average reservoir pressure with the oil production obtained over a certain period of time. The constants in the equation, which express the physical properties of the fluids in the Woodbine sand as well as the thickness and properties of the sand itself, are as follows:

c, expansibility of fluids in the Woodbine sand.
H, effective thickness of Woodbine sand body.
K, average permeability of Woodbine sand body.
ϕ, porosity of Woodbine sand body.

Application to East Texas Field

In order to apply the ideal analysis to the actual East Texas water-drive problem, it was expected that it would be necessary to make certain allowances and corrections for those discrepancies by which the ideal analysis does not fit the actual problem. This was necessary, but it was found that correction for the irregularities could readily be made by adjusting only one constant; namely, the value for the expansibility of the water in the Woodbine sand. The values used for the constants are:

$c = 2.75 \times 10^{-7}$ cu. ft. per cu. ft. per pound per square foot.
$H = 200$ ft.
$K = 0.035$ cu. ft. of fluids flowing per day per square foot of cross-section per pound per square foot pressure differential per foot length of flow.
$\phi = 25$ per cent.

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* For definition of symbols, see table of nomenclature at end of paper.

The values given for the thickness, permeability and porosity of the sand are the best estimates that could be arrived at from such laboratory and field data as were available. It is pointed out that by "thickness of sand" is not meant that of the oil reservoir itself, but rather an average thickness of that portion of the water-filled Woodbine sand influenced by production from the field. It is a known fact that the Woodbine sand increases in thickness considerably to the west of the field. The constants for permeability and porosity have been taken from laboratory determinations on core samples. The adjusted constant used for the expansibility of the water in the Woodbine formation is a little over 10 times the actual value for pure water.

Using the values for the constants as given, the variations in the average reservoir pressure of the East Texas field have been calculated over the very irregular production history of the field. The results are shown graphically as the dashed line in Fig. 1, while the actually observed values for the average pressures are the plotted points. It is observed that a close check with the actual data has been obtained. In particular, it is pointed out that the several increases in pressure, observed during periods of shutdown or following reduction in the production rate, have been checked by the calculation.

The fact that it has been possible to take care of all irregularities by making an adjustment in only one constant is remarkable, particularly when it is realized that the adjusted value used instead of the expansibility of pure water is not at all unreasonable. It is known that the Woodbine water contains dissolved or occluded gases. Although their exact effect has not been determined, undoubtedly such associated gases would greatly augment the expansive power of the water. In a similar manner the oil and gas fields, scattered throughout the Woodbine basin, would cause the water to behave as though it were a more expansible fluid.

In view of the good check with the actual data and in order to show more clearly the influence of the production rate upon the average reservoir pressure, the changes in the average pressure under several assumed rates of production have been calculated for the year August, 1934, to August, 1935. These results are also given in Fig. 1 for production rates of 0; 200,000; 400,000; 600,000; 800,000; and 1,000,000 bbl. per day. The curve for zero production rate indicates that the pressure would build up from about 1228 lb. per sq. in. to nearly 1400 lb. per sq. in. by August, 1935, if the field were shut in. At a production rate of 400,000 bbl. per day, the average pressure would probably remain above 1200 lb. per sq. in. through August, 1935, but at 1,000,000 bbl. per day would decline rapidly to below 1000 lb. per sq. in. It is interesting to compare the predicted average rates of pressure decline expressed as pounds per square inch per million barrels of oil produced for the several assumed rates of production (Table 1), which shows that the pressure decline during the year per million barrels of oil produced would be over eight times as rapid at a production rate of 1,000,000 bbl. per day as at 400,000 bbl. per day.

TABLE 1.—*Predicted Rates of Pressure Decline*

Assumed Rate, Bbl. per Day	Total Production, Aug. 1934–Aug. 1935	Predicted Pressure, Aug. 1935, Lb. per Sq. In.	Predicted Pressure Change, Aug. 1934–Aug. 1935, Lb. per Sq. In.	Pressure Change, Lb. per Sq. In. per Million Bbl. Produced
200,000	73,000,000	1,305	+ 77	+1.05
400,000	146,000,000	1,215	− 13	−0.09
600,000	219,000,000	1,130	− 98	−0.45
800,000	292,000,000	1,035	−193	−0.66
1,000,000	365,000,000	945	−283	−0.78

As mentioned before, the pressures are being lowered progressively in the Woodbine sand to the west of the East Texas field. The equations developed have also been used to gain some idea as to the extent of this decline in pressure. In Fig. 4 is shown the calculated pressure gradient for August, 1934, extending from the East Texas field out into the Woodbine formation. The curve indicates that the pressures have been lowered about 125 lb. per sq. in. at a distance of 5 miles and, further, that the influence of production from the East Texas field may be felt at a distance approximately 10 miles out in the Woodbine sand.

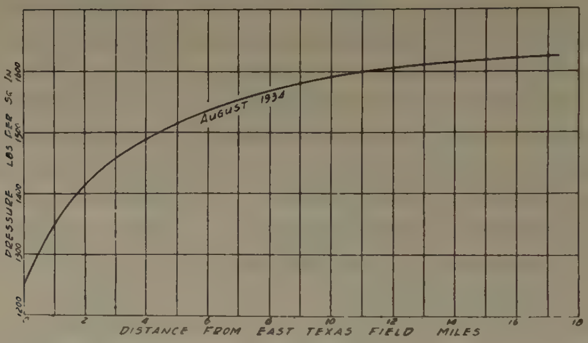

FIG. 4.—PRESSURE GRADIENT SET UP IN WOODBINE SAND BY PRODUCING EAST TEXAS FIELD.

CONCLUSIONS

The data on the East Texas field indicate clearly that water drive or water encroachment is by far the most important agency in maintaining the reservoir pressure or in producing the oil. From the analysis described herein, it appears that the water moves into the field by virtue of its own expansion upon reduction of pressure, and not, as in many cases, by flowing through the entire formation from its surface outcrop to the field. The effect of the expansive power of the water underlying the oil is probably an important factor in a great many oil fields, yet this factor has been overlooked by most geologists and engineers in their investigations of the mechanism of oil production.

The close agreement, as shown in Fig. 1, between the calculated behavior of the average reservoir pressure in the East Texas field and that actually observed indicates that the analysis can be used to predict changes in the average pressure over a reasonable period of time. Such calculations have important practical application in the estimation of the flowing life of the field, the determination of the proper rate of production, and similar problems.

ACKNOWLEDGMENTS

The authors are indebted to T. V. Moore, in charge of production research work at the Humble Oil & Refining Co., who has directed the work and aided materially in the preparation of this paper.

NOMENCLATURE

P_R, original reservoir pressure, lb. per sq. in.
P_F, reservoir pressure at any time, lb. per sq. in.
q_F, production rate at any time, bbl. per day.
ρ, density of oil and gas mixture at P, lb. per cu. ft.
K, permeability of sand, cu. ft. per day per sq. ft. per lb. per sq. ft. per ft.
c, expansibility of fluids, cu. ft. per cu. ft. per lb. per sq. ft.
ϕ, porosity, fraction.
α^2, ratio, $\frac{K}{\phi c}$.
θ, time, days.
a, half length of field, ft.
x, distance along coordinate parallel to north-south axis of field.
y, distance along coordinate perpendicular to north-south axis of field.

REFERENCES

1. Lindsly: A Study of Bottom-hole Samples of East Texas Crude Oil. U.S. Bur. Mines R.I. 3212 (1933).
2. Hudnall: Address delivered before A.A.P.G. at Dallas, Texas, in March, 1934.
3. Lewis: Rock Pressure. *Petr. Engr.* (May, 1934).
4. Hurst: Unsteady Flow of Fluids in Oil Reservoirs. *Physics* (1934) **5**, 20.
5. Moore, Schilthuis and Hurst: The Determination of Permeability from Field Data. *Oil Weekly* (May, 1933) **69**.
6. Watson: Theory of Bessel Functions, 450. Cambridge Univ. Press, 1922. Gray and Mathews: A Treatise on Bessel Functions, 77. Macmillan, 1895.

DISCUSSION

(*T. V. Moore presiding*)

R. D. WYCKOFF,[*] Pittsburgh, Pa.—At the meeting in Ponca City two years ago I objected to the assumption of a 100 per cent water drive in the East Texas field because, on simple artesian flow theory, calculation showed that it was impossible to get the required volume of water encroachment under the existing pressure conditions. Furthermore, field measurements indicated variable gas-oil ratios that could obtain only if free gas were present in the sand and, in addition, declining pressures were being observed which, under simple artesian theory, would definitely indicate less than 100 per cent water drive. Thus the evidence at our disposal led us to no objection to a partial gas drive.

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[*] Gulf Research & Development Corporation.

We have since had available the gas-saturation measurements for the East Texas field as obtained by Mr. Lindsly, which show conclusively that no gas is released from the oil above 750 lb. reservoir pressure. We were forced by this later evidence to obtain a 100 per cent water drive by considering the compressible fluid theory. Mr. Moore had pointed out the necessity of considering the compressibility of the water in the Woodbine basin, during the Ponca City discussion.

In view of the importance of the subject, I am including a drawing (Fig. 5) showing the calculated pressure decline of the East Texas field as compared with the observed decline. The calculations follow the theory presented by Dr. Muskat's paper on compressible fluid flow[7] and represent results obtained by a slightly different method than that used by the authors. Thus, being an entirely independent check, it may aid in stressing the importance of the compressible fluid theory in consideration of water drives.

In Fig. 5 the calculated pressures represent west-edge pressures and are, therefore, higher than the observed average field pressures because of the west-to-east pressure gradient across the field, the magnitude of which is approximately proportional to the production rate. The circles show the observed average pressures corrected to west-edge conditions by adding a correction factor that is proportional to the daily production rate. A remarkably good agreement is obtained except where abrupt changes in rate occur, giving rise to transients in the gradient across the field not accounted for in the simple correction factor, as well as to some uncertainty in the actual output of the field.

Quite independently, we obtain about the same physical constants as have been presented in this paper, and the apparent effective compressibility of the water in the Woodbine horizon adjacent to the East Texas field is about 12 times the normal value for water.

R. J. Schilthius.—The water drive is likely to be important in other fields. I think that we can accomplish more by attacking the problem along this line than through equilibrium studies.

F. Herald,* Ft. Worth, Texas.—Was there a correction factor? What was it?

R. A. Cattell,† Washington, D. C.—What were the pressures? Were they actual pressures or calculated?

T. V. Moore,‡ Houston, Texas.—They were the average of shut in pressures on from 300 to 400 wells.

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[7] M. Muskat: The Flow of Compressible Fluids through Porous Media and Some Problems in Heat Conduction. *Physics* (March, 1934) **5**, 71.

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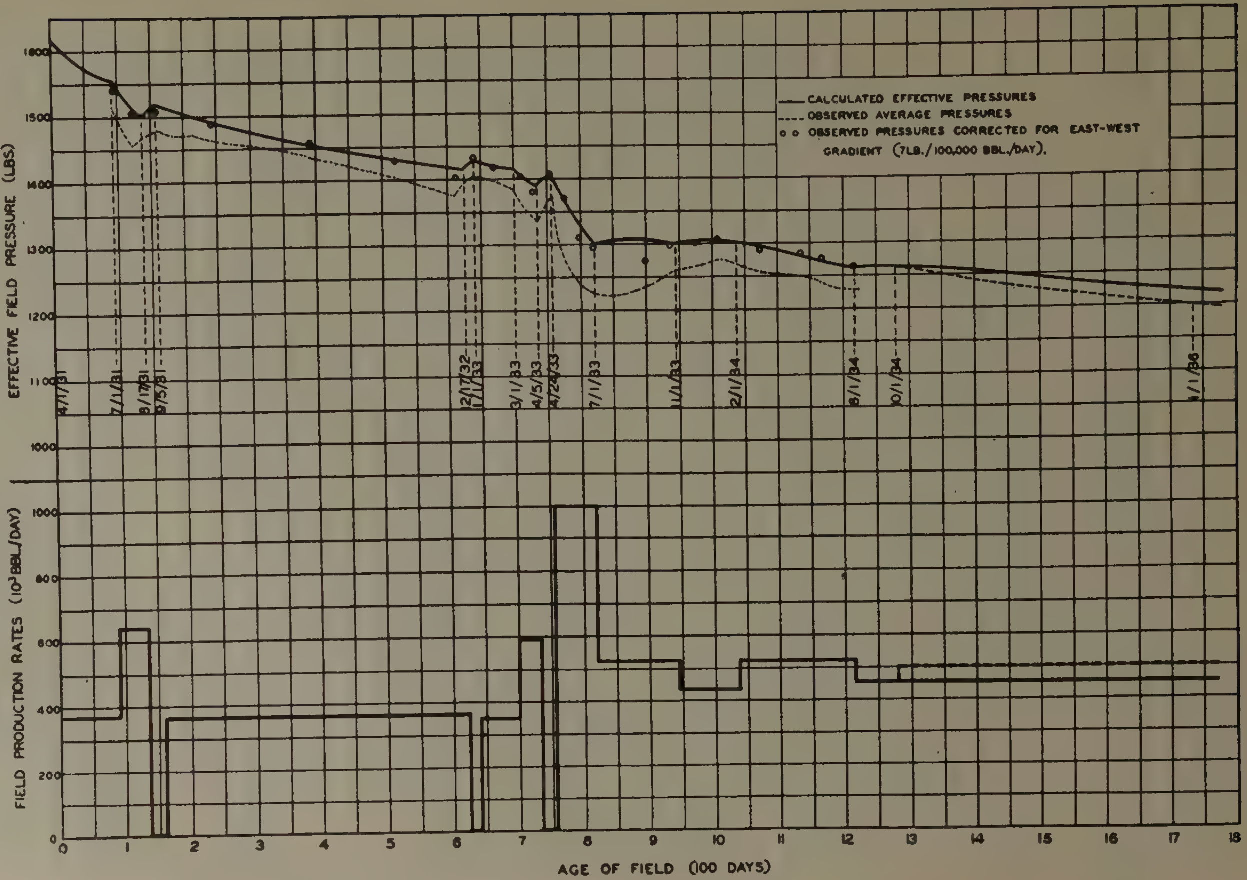

FIG. 5.—CALCULATED PRESSURE DECLINE OF EAST TEXAS FIELD COMPARED WITH OBSERVED DECLINE.

H. D. Wilde, Jr.,* Houston, Texas.—Laboratory data on the compressibility of the water in place in the Woodbine sand are not available. Although the compressibility used in the paper is about twelvefold that given in International Critical Tables, it must be remembered that the value in the tables is for pure distilled water. Small quantities of dissolved gases and salts in the Woodbine water can easily account for its greater compressibility. The value used was arrived at one or two years ago. Using this value it has been possible to predict accurately the actual pressure changes that have occurred during this period.

F. Herald.—Approximately how many wells in the East Texas field are there in which the water has risen more than 10 feet?

M. Albertson,† Houston, Texas.—The average rise of the water table was recently estimated to be slightly less than 10 feet.

T. V. Moore.—There is no conclusive proof that the average rise of the water table has been 10 feet.

E. A. Stephenson,‡ Rolla, Mo.—The best check on the accuracy of formulas comes in their application to future conditions. In this instance the problem was approached by individuals who originally had totally different viewpoints regarding the phenomena involved. However, in both cases their independent mathematical analyses led to predictions concerning conditions at the East Texas field which subsequently were substantiated by the facts. As a result a new "tool" is available with which to forecast pressure conditions or demonstrate rates of withdrawal in the East Texas field.

R. J. Schilthuis.—It was necessary to set up the analysis of the East Texas water-drive problem for an ideal case, as it is, of course, impossible to account, in the analysis, for all of the irregularities in the shape of the East Texas field and Woodbine sand, and the variations in thickness, permeability and porosity of the sand which undoubtedly exist. As expected, it was necessary to make a correction or adjustment in the equations derived under the ideal case to make them applicable to the actual problem. Of the constants in the equations, that expressing the compressibility or expansibility of the water in the Woodbine sand to the west of the East Texas field was thought to be the one about which least was known, and by means of which it was found by trial that the required adjustments could be made most easily. The value of the adjusted constant which makes the ideal equations applicable to the actual problem is a little more than 10 times the value of the compressibility of pure water. It would be expected that the value should be somewhat higher than the compressibility of pure water, as the Woodbine water is more than likely saturated with gas, which would increase the water's power of expansion. Furthermore, any oil or gas fields in the Woodbine basin, either discovered or undiscovered, that exist not too far away from the East Texas field would cause the water to behave as though it were a more expansible fluid.

In applying the equations to the problem, it was not necessary to make an estimate of the total quantity of water in the Woodbine basin. The process of flow is such that the water is caused to expand and flow toward the field from progressively greater and greater distances out in the Woodbine sand to the west of the field. The equations automatically take this into account.

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Chapter II. Use of Metals in the Petroleum Industry

Economical Selection of Sucker Rods

By Blaine B. Wescott* and C. Norman Bowers*

(New York Meeting, February, 1935)

Marked improvement in the serviceability of sucker rods has been effected in the last two years, partly because of the insistent necessity for greater economy in the operating costs of crude oil production growing out of the general industrial depression and partly because many of the recently developed fields have imposed more severe operating conditions upon both surface and underground equipment. The latter is particularly true of Kansas, where practically all of the oil produced is associated with damaging amounts of hydrogen sulfide brine and where the method of establishing potential production demands equipment capable of being operated at maximum capacity without interruptions. The decline of flush production in the Oklahoma City field created new problems in deep-well pumping on a scale heretofore unequaled and the increased proportion of water it has been necessary to produce in the fields of the Greater Seminole area presented conditions that were acutely in need of betterment. The problem in the latter fields was complicated by the shift towards sulfide characteristics, which accompanied water encroachment, and it is probably true that nowhere, at the present time, are pumping conditions generally as severe as in this territory. The Mid-Continent district, therefore, has become the proving ground for the numerous materials that have been proposed for sucker-rod fabrication. The information that ultimately will be obtained from an unprecedented amount of field experimentation will pay ample dividends when the decline of East Texas increases the demand for the vast reserves of sour crude in West Texas.

It is a rare occurrence in industry that the use of such a simple piece of equipment as a sucker rod presents so complicated a problem for solution. As proof of this, it is only necessary to consider the numerous types of sucker rods on the market at the present time and contrast this condition with that of less than four years ago, when it was the common aim of manufacturers to develop a single sucker rod for all conditions of

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service. It is now recognized that this cannot be done economically, consequently manufacturers are offering from two to eight separate and distinct grades of sucker rods, in addition to which nearly all of these grades are made in both double pin and box and pin types in both 25 and 30-ft. lengths. Obviously, such a wide variety is not conducive to low manufacturing costs, nor does it simplify the problem of the user in selecting the most suitable grade of sucker rods for any particular kind of service.

CLASSIFICATION OF WELLS

The present is a period of experimentation that will terminate, in all probability, in less than two years, with, at most, four grades of sucker rods, which will be sufficient to satisfy the requirements of all classes of pumping service. The two most important factors to be considered when selecting sucker rods are the weight of the well and the degree of corrosivity of the fluid produced. The first of these factors is fixed by the depth to the fluid, size of pump, length and speed of stroke and the gravity of the fluid produced. The weight of a well, or, perhaps more accurately, the stresses imposed on sucker rods may be varied almost at will by adjustments of the three pumping conditions subject to control of the operator; namely, the size of pump and the length and speed of stroke. Sucker-rod failures can literally be controlled at will by regulation of pumping conditions, and it becomes the problem of each operator to decide when the proper economic balance is obtained between value of extra oil produced and cost of the consequent increased well trouble.

The degree of corrosivity of the fluid produced is determined generally by the presence or absence of hydrogen sulfide. Hydrogen sulfide, which is usually associated with production from lime and seldom from sand, always is responsible for increased trouble from underground equipment if water is being produced with the oil; in the absence of water it presents no problem. While there are certain nonsulfide fields that produce corrosive brine with the oil, the problems they present are neither as numerous nor as serious as those encountered in the sulfide fields.

The kinds of service, therefore, for which sucker rods should be designed are: (1) noncorrosive fields; (2) corrosive, nonsulfide fields; (3) corrosive, sulfide fields. There are no sharp dividing lines between these three classes of service nor does it necessarily follow that all wells within a single field belong in the same class. Occasionally it may be found advantageous to subdivide one or more of the classes into light and heavy pumping wells. In the final analysis, it is advisable to make the classification in accordance with the grouping suggested, or by any other method that may be preferred, after consideration has been given to each well individually. It is essential that adequate individual well records be available if the greatest economy in production operations is to be assured.

Sucker-rod failures are not excessive in the noncorrosive wells or fields (class 1 above) and satisfactory sucker rods for these conditions have long been procurable. This is not true, however, of the corrosive conditions (classes 2 and 3 above) and a sizable degree of effort is being applied to the development of suitable rods for these purposes at the present time. In common with nearly all other corrosion problems, the real difficulty in solution is introduced by the necessity for providing a comparatively inexpensive material or materials for the purpose. Also in common with numerous other similar problems, the greatest ultimate economy is frequently not obtained if the selection of sucker rods is made only on the basis of original cost.

PROPERTIES OF MATERIALS

There is no single physical property by which the suitability of a steel or iron for sucker rods may be judged. Furthermore, the common physical properties as ordinarily provided are of little value in making a selection of sucker rods, and if the choice is based solely on these properties it is certain to prove expensive in many instances. Some of the physical properties that are not ordinarily determined are of much greater importance and should be given careful consideration.

The typical compositions of the various types of steels and irons used for sucker rods at this time are given in Table 1, which also includes the relative costs with respect to the cheapest plain carbon-steel sucker rod. The regularly reported, representative physical properties of these alloys

TABLE 1.—*Chemical Compositions and Relative Costs of Sucker-rod Materials*

Type	Constituent, Per Cent									Relative Cost Based on Cheapest Sucker Rod
	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Other Constituents	
S.A.E. 1035	0.370	0.830	0.018	0.033	0.110					1.00
S.A.E. 1045	0.450	0.840	0.027	0.041	0.210					1.00
S.A.E. 1050	0.510	0.730	0.015	0.047	0.180					1.09
S.A.E. 3130	0.340	0.650	0.015	0.020	0.190	0.580	0.990			1.25
S.A.E. 4130	0.310	0.620	0.013	0.020	0.240	0.720		0.210		1.40
S.A.E. 4615	0.180	0.510	0.012	0.006	0.230		1.570	0.240		1.22
1.25 per cent manganese	0.360	1.170	0.024	0.021	0.190					1.07
1.75 per cent manganese	0.380	1.910	0.023	0.016	0.210					1.13
Toncan iron	0.050	0.290	0.009	0.006	0.050			0.110	0.510 copper	1.20[a]
Wrought iron	0.030	0.040	0.083	0.012	0.160				4.200 slag	1.30
Nickel wrought iron	0.030	0.040	0.077	0.027	0.110		3.000		2.750 slag	1.79
Nickel iron	0.030	0.010	0.003	0.006	0.030		3.520			1.45
Nickel molybdenum iron	0.040	0.130	0.002	0.007	0.030		2.900	0.140		1.42

[a] Estimated.

TABLE 2.—*Static Physical Properties of Sucker-rod Materials*

Type	Heat Treatment[a] Deg. F.			Yield Point, Lb. per Sq. In.	Tensile Strength, Lb. per Sq. In.	Elongation, Per Cent in 2 In.	Reduction of Area, Per Cent	Charpy Impact Ft-lb.	Brinell Hardness Number
	Quench	Normalize	Draw						
S.A.E. 1035........				55,500	88,500	31.3	56.4	30.3	169
S.A.E. 1045........		1,600		62,300	96,500	28.3	52.3	19.2	191
S.A.E. 1050........	W 1,550		1,100	100,700	123,200	21.5	59.4	29.7	230
S.A.E. 3130........		1,600		81,900	100,500	27.8	70.6	51.8	213
S.A.E. 4130........	W 1,550		1,150	111,300	128,500	16.6	67.2	40.5	267
S.A.E. 4615........				58,500	84,700	29.0	66.0	33.7	171
1.25 per cent manganese..........				71,300	100,000	28.8	63.9	34.6	206
1.75 per cent manganese..........		1,500		72,900	118,200	23.5	56.3	32.1	235
Toncan iron.......				43,100	51,900	43.3	80.5	55.1	106
Wrought iron......				42,100	47,700	33.6	46.4	19.9	74
Nickel wrought iron				58,100	63,900	31.0	50.2	24.0	149
Nickel iron........				47,900	58,100	40.8	72.3	44.5	125
Nickel molybdenum iron.............				52,500	63,600	37.8	70.3	43.5	140

[a] W indicates water quench.

are given in Table 2. These two tables indicate the wide variations both in composition and properties of the materials being utilized and emphasize the fact that sucker rods are passing through a transitory stage of development that is not at all characterized by unanimity of opinion.

The much less commonly reported fatigue or endurance properties of the same steels and irons are given in Table 3. The endurance limits were determined under three conditions of test; in air (i.e., no corrosion), immersed in oil-well brine and immersed in oil-well brine saturated with hydrogen sulfide. The manner in which these tests were conducted has been described elsewhere[2] and need not be repeated here. Also, the relation between experimentally determined endurance limits and those obtaining in actual operations was discussed in some detail and it was pointed out that while the two are not the same the experimentally determined values serve as a reliable means for the comparative classification of materials in their proper order of expected field performance. Since, as stated above, the most severe service is imposed on sucker rods in the sulfide fields, the most significant property is the hydrogen sulfide endurance limit. The great reduction in these values when compared to the ordinary endurance limits provides ample proof of this statement. The actual magnitude of this reduction for any particular material is a measure of the damage suffered as a result of the presence of the highly corrosive sulfide brine and is expressed, in Table 3, as the ratio of sulfide corrosion endurance limit to air endurance limit. The damage is not constant for all materials and it is considerably less for the alloys of low carbon content. The lowering of the endurance limits in sulfide brine is not due solely to the greater corrosivity of the fluid; it is partly due to the embrittling action of hydrogen sulfide and it is also influenced by the susceptibility of the respective materials to stress concentration at the base of corrosion pits.

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[2] B. B. Wescott and C. N. Bowers: Corrosion Fatigue and Sucker Rod Failures. Amer. Petr. Inst. Fourteenth Annual Meeting, Chicago, Ill., Oct. 24, 1933.

TABLE 3.—*Endurance Properties of Sucker-rod Materials*

Type	Heat Treatment[a] Deg. F.			Endurance Limit (Lb. per Sq. In.)			Ratios	
	Quench	Normalize	Draw	Air, AL	Corrosion, CL	Sulfide Corrosion, SL	CL/AL	SL/AL
S.A.E. 1035				40,600	24,600	10,600	0.61	0.26
S.A.E 1050	W 1,550		1,100	66,900	25,600	14,100	0.38	0.21
S.A.E. 3130		1,600		55,100	31,600	15,900	0.57	0.29
S.A.E. 4130	W 1,550		1,150	70,100	26,900	14,100	0.38	0.20
S.A.E. 4615				48,600	33,100	19,900	0.68	0.41
1.25 per cent manganese				48,900 45,800[b]	19,600	14,600	0.40	0.30
1.75 per cent manganese		1,550		56,400	29,400	12,100	0.52	0.21
Toncan iron				36,400	16,900	11,900	0.46	0.33
Wrought iron				30,400	19,600	16,400	0.64	0.54
Nickel wrought iron				42,600 39,500[b]	25,100	18,600	0.59	0.44
Nickel iron				39,600	26,900	19,100	0.68	0.48
Nickel molybdenum iron				45,100	25,400	21.900	0.56	0.49

[a] W indicates water quench.

[b] Values determined for complete reversal of axial stress by Haigh axial testing machine at the Research Laboratories of the Westinghouse Electric & Manufacturing Co.

Instances of extreme brittleness of sucker rods are of quite frequent occurrence and this is caused by the action of hydrogen sulfide upon the steel. Relatively short exposure to the gas in the presence of water will embrittle steel seriously without any visible manifestation of the action either to the eye or at high magnification. The yield point and tensile strength are not affected, but there is a marked decrease in toughness, the extent of which can best be determined from measurements of elongation and reduction of area as given by ordinary tensile tests. Not all irons and steels are embrittled to the same extent and this factor should be considered in selecting sucker rods for use in sulfide fields. The extent to which some of the sucker-rod steels are embrittled is given in Table 4. Of the six materials tested the 1.75 per cent manganese steel was embrittled to the greatest extent and the nickel iron was least affected. The manner in which the action of hydrogen sulfide is manifested is illustrated by Fig. 1. The tensile-test specimen at the left is nickel iron in the hot-rolled condition, second from the left is a specimen of the same material after exposure to moist hydrogen sulfide. The two specimens on the right are 1.25 per cent manganese steel before and after exposure, respectively. In addition to loss of ductility the action of the gas entirely changes the nature of the fracture from the ordinary cup and cone appearance to one largely resembling failure by shear. From this fact and because of the short exposure required for embrittlement and the lack of visible evidence, it seems probable that the action is intercrystalline. Interaction between hydrogen sulfide and iron results in the formation of nascent hydrogen, which is adsorbed at the intercrystalline boundaries of the steel. The change of the adsorbed atomic hydrogen to molecular hydrogen is accomplished with increase in volume and consequent development of enormous internal pressure in the steel, which causes the loss in toughness and decreases the resistance to shock. It has been

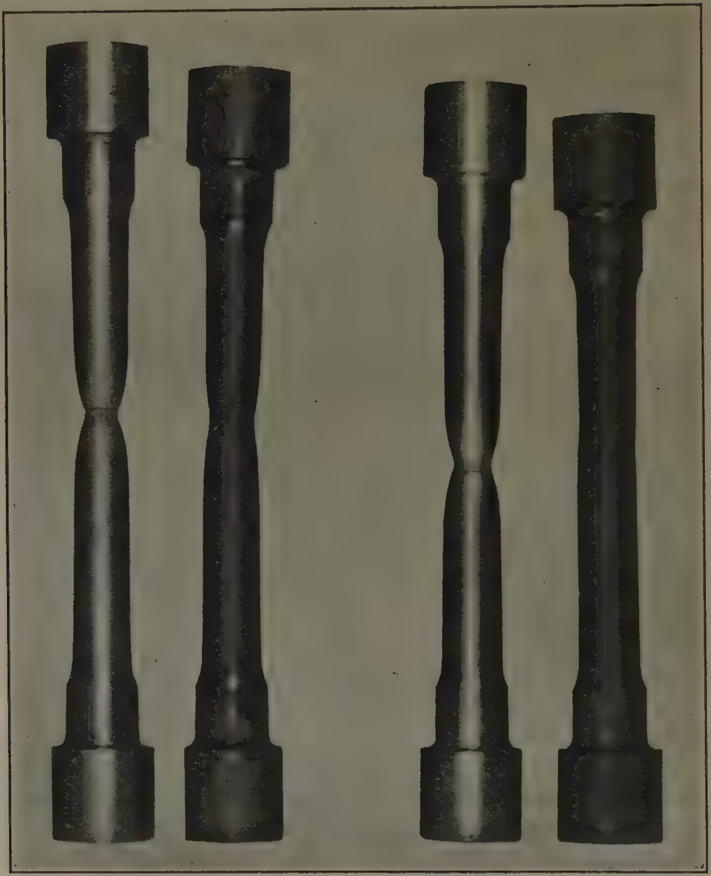

Fig. 1.—Embrittlement of steel by hydrogen sulfide.

Left to right; nickel iron before exposure, nickel iron after exposure, 1.25 per cent manganese steel before exposure, 1.25 per cent manganese steel after exposure.

shown[3] that if the metal is already under high internal stress, i.e., in a cold-drawn condition, exposure to hydrogen sulfide for a very short time only may cause spontaneous rupture of the steel. It is, therefore, reasonable to suppose that a given steel would suffer more severely from this action in the heat-treated condition than in the annealed or even hot-rolled condition. Upon mild heating, or rather extended standing at atmospheric temperatures, steel recovers practically all of the ductility lost as a result of exposure to hydrogen sulfide.

TABLE 4.—*Embrittlement of Sucker-rod Steels by Hydrogen Sulfide*

Material and Condition	Before Exposure to Hydrogen Sulfide		After Exposure to Hydrogen Sulfide		Per Cent Decrease (Embrittlement)	
	Elongation, Per Cent in 2 In.	Reduction in Area, Per Cent	Elongation, Per Cent in 2 In.	Reduction in Area, Per Cent	Elongation	Reduction in Area
1.25 per cent manganese, as rolled	29.0	64.2	21.5	37.6	25.9	41.5
1.25 per cent manganese, normalized	27.5	64.5	17.8	34.3	35.3	46.8
1.75 per cent manganese, normalized	28.5	66.0	17.0	23.8	40.4	63.9
S.A.E. 4615, as rolled	29.0	66.0	18.7	30.8	35.5	53.3
Nickel wrought iron, as rolled	31.0	50.2	22.5	29.0	27.4	42.1
Nickel iron	40.8	72.3	32.0	45.5	21.6	37.1

Corrosion of iron or steel in the presence of hydrogen sulfide generally causes pitting of the surface, and surface pits in turn cause stress concentration because the continuity of the surface is disrupted. The base of a corrosion pit in a sucker rod, therefore, is a point of highly localized stress, and if the operating stresses are high it is possible for the unit stress at these points to exceed the endurance limit of the material. If this happens, and the stress does not at the same time exceed the yield point, an incipient crack will be developed, which ultimately will cause a fatigue failure. If, however, both the endurance limit and the yield point are exceeded at a point, the material will yield in a plastic manner and effect a redistribution of stress without the formation of the incipient crack. In order to classify sucker-rod materials with regard to their respective abilities to withstand highly localized stresses, a series of tests was made to determine the endurance limits of notched specimens. In the absence of corrosion, the stress-concentration factors so found indicate the relative degrees of sensitivity of the materials to surface discontinuities. The results are given in Table 5. It is apparent that the ratio of the depth of the notch (pit) to the section of the specimen has a marked effect on the stress-concentration factor. The exact shape of the notch also influences the results, the concentration of stress being greater as the sharpness of the notch at its root increases. The low-carbon nickel alloys have greater resistance to stress concentration than the medium-carbon 1.25 per cent manganese steel. Practically the same results were obtained from transverse and longitudinal methods of stressing.

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[3] L. W. Vollmer and B. B. Wescott: Effect of Hydrogen Sulfide on Wire Rope. Amer. Soc. Mech. Engrs. National Petroleum Meeting, Tulsa, Okla., Oct. 6 to 8, 1930.

Table 5.—*Stress-concentration Factors of Sucker-rod Steels*

(60° groove having a radius of 0.0065 in. at its extremity.)

Material and Condition	Endurance Limit, Lb. per Sq. In.		Ratio of Depth of Groove to Diameter of Specimen	Stress-concentration Factor
	Unnotched	Notched		
Armco ingot iron (hot-rolled)	32,100	21,100	0.013	1.52
Wrought iron (double refined)	30,400	19,600	0.013	1.55
Nickel wrought iron (normalized 1600° F.)	41,100	29,900	0.013	1.37
Nickel iron (normalized 1600° F.)	42,400	29,600	0.013	1.43
Nickel wrought iron (hot-rolled)	42,600	16,900	0.100	2.52
	39,500[a]	16,800[a]	0.100	2.35
1.25 per cent manganese steel (hot-rolled)	48,900	27,100	0.050	1.80
		16,900	0.100	2.90

[a] Results obtained from tests on Haigh axial testing machine at the Research Laboratories of the Westinghouse Electric & Manufacturing Company.

Table 6.—*Tensile Impact Properties of Sucker-rod Materials*

Type	Heat Treatment,[a] Deg. F.			Impact Resistance		Elongation, Per Cent in 2 In.	Reduction of Area, Per Cent
	Quench	Normalize	Draw	Ft-lb.	Ft-lb. per Sq. In.		
S.A.E. 1045		1,600		124.2	4,880	26.7	53.8
S.A.E. 1050	W 1,550		1,100	109.2	4,310	18.5	61.7
S.A.E. 3130		1,600		110.0	4,320	22.7	72.1
S.A.E. 4130	W 1,550		1,150	82.8	3,260	14.0	68.3
S.A.E. 4615				116.2	4,570	29.3	66.2
1.25 per cent manganese				120.0	4,700	24.5	65.5
1.75 per cent manganese		1,550		112.8	4,440	19.0	65.0
Toncan iron				106.5	4,190	37.0	71.5
Wrought iron				65.7	2,590	22.0	30.8
Nickel wrought iron				83.7	3,300	29.0	36.6
Nickel iron				114.8	4,520	41.2	75.7
Nickel molybdenum iron				118.7	4,670	39.5	74.3

[a] W indicates water quench.

Some speculation has been connected heretofore with the effect of instantaneous shock loads of high magnitude on the different steels, giving rise to uncertainty as to which types are best able to resist this action. Tensile impact tests furnish some information in answer to this question. Results of such tests on sucker-rod materials, given in Table 6, bring out several interesting facts. There is an exceedingly close agreement between the values for elongation and reduction of area as determined in regular tensile tests (Table 2) and in the tensile impact tests. The unit tensile impact resistance is more closely related to ductility as determined by reduction in area from tensile tests than to any other of the regularly determined physical properties. There is no apparent relationship between tensile impact strength and either tensile strength or yield point, since, for example, S.A.E. 4130 steel, heat-treated to a tensile strength of 128,500 lb. per sq. in., had practically the same tensile impact resistance as the nickel wrought iron with a tensile strength of only 63,900 lb. per sq. in. Apparently internal stress such as results from full heat treatment (quench and draw) or structural heterogeneity such as is characteristic of wrought iron tends to have a deleterious effect on tensile impact resistance.

Evaluation of Materials

The value of data on the properties of materials is dependent, of course, upon the extent to which it can be translated into the purchase of equipment that will be most economical for a given purpose. In attempting to apply these data to sucker rods, it is important to consider what operating stresses they will be subjected to. There is ample information available to conclude that stresses of 30,000 lb. per sq. in. are not uncommon in Mid-Continent wells even when graduated strings of ⅞-in. and ¾-in. sucker rods are used. In corrosive fields where pitting occurs, this stress may be increased by a factor of from 1.3 to 2.5 because of stress concentration at the bottoms of pits, with the result that the stress at such points considerably exceeds the endurance limit. The average stress-concentration factor is probably between 1.5 and 2.0, so that the localized stresses may occasionally be as high as 60,000 lb. per sq. in. The desirability of having the yield point low enough to be exceeded and thus permit redistribution of stresses has been alluded to. It has been concluded, therefore, that for this type of service—in sulfide fields—the sucker-rod material should have a yield point between 50,000 and 60,000 lb. per sq. in. At the same time, maximum ductility and toughness should be provided by keeping the carbon content less than 0.10 per cent. The alloying elements used to obtain the yield point specified above should preferably belong to the class that forms solid solutions with the ferrite; carbide-forming elements are less desirable. High endurance and corrosion-endurance limits are of great importance, although it is probable that various materials will not differ greatly in this respect if the other properties have been properly regulated. The tensile strength does not appear to be of any sensible moment so long as the other properties meet the requirements.

An effort has been made to develop a more or less exact method for the evaluation of materials for operation under sulfide conditions by means of the following equation:

$$V = (1 - 5X^2)\frac{(SL)^3}{W \times 10^6} \qquad [1]$$

where V = the index value,

$X = \dfrac{\text{yield point} - 55{,}000}{55{,}000}$,

SL = sulfide corrosion endurance limit,

W = calculated unit stress for any given conditions of operation.

This formula is based on the assumption that the optimum yield point for these conditions is 55,000 lb. per sq. in. The index value is lowered at an increasing rate by departures in yield point either above or below the optimum value and is proportional to the cube of the endurance limit. Attempts to evaluate materials on a basis of physical properties are of somewhat uncertain dependability and admittedly are empirical and arbitrary, but while the proposed equation is not an exception there is considerable evidence in its support from actual service records. The formula is applicable only to materials with yield points between the minimum value of 31,000 lb. per sq. in. and the maximum value of 79,000 lb. per sq. in. Field experience indicates that materials with yield points lower than 40,000 lb. per sq. in. or greater than 70,000 lb. per sq. in. are quite unsuited for this type of service.

To illustrate the application of this formula, several materials have been evaluated for expected service at a peak load of 30,000 lb. per sq. in. (Table 7). To decide whether a more expensive material would be justified for any particular case the initial cost and repair expense of the cheaper material would be compared with the initial cost and the repair expense of the more expensive material estimated from the comparison of the respective index values of the two.

The index values cannot be applied too literally, since the formula by which they are calculated does not take into account two important interdependent factors, time and overstressing. Materials in fatigue service, i.e., subjected to repetitive stressing, behave differently when the applied stresses exceed the endurance limit. Since failures occur, this is the condition (overstressed) under which sucker rods operate. The fatigue curves (S-N diagrams) of four sucker-rod materials in air and in sulfide corrosion are given in Fig. 2. The endurance limit is the stress at which these curves either approach or become horizontal. For

TABLE 7.—*Calculated Index Values for Expected Service of Sucker-rod Materials*

(Assumed peak load 30,000 lb. per sq. in. in corrosive sulfide service.)

Type	Yield Point, Lb. per Sq. In.	Sulfide Corrosion Endurance Limit, SL, Lb. per Sq. In.	Index Value
S.A.E. 1035	55,800	10,600	39.6
S.A.E. 4615	58,500	19,900	257.0
1.25 per cent manganese, hot-rolled	71,300	14,600	58.0
1.75 per cent manganese, normalized	72,900	12,100	27.7
Toncan iron	43,100	11,900	43.1
Wrought iron	42,100	16,400	106.6
Nickel wrought iron	58,100	18,600	211.0
Nickel iron	47,900	19,100	213.0
Nickel molybdenum iron	52,500	21,900	346.5

steels the curves become truly horizontal in the absence of corrosion, but they never become truly horizontal in corrosion-fatigue; the divergence increases with increasing degree of corrosivity. The portions of the curves to the left of the abrupt change in slope describe the behavior in the region of overstressing. It is characteristic of all materials being discussed that the damage from overstressing is much less in the absence of corrosion. Stated somewhat differently, under corrosive conditions overstressing will cause sucker-rod failures in a much shorter period

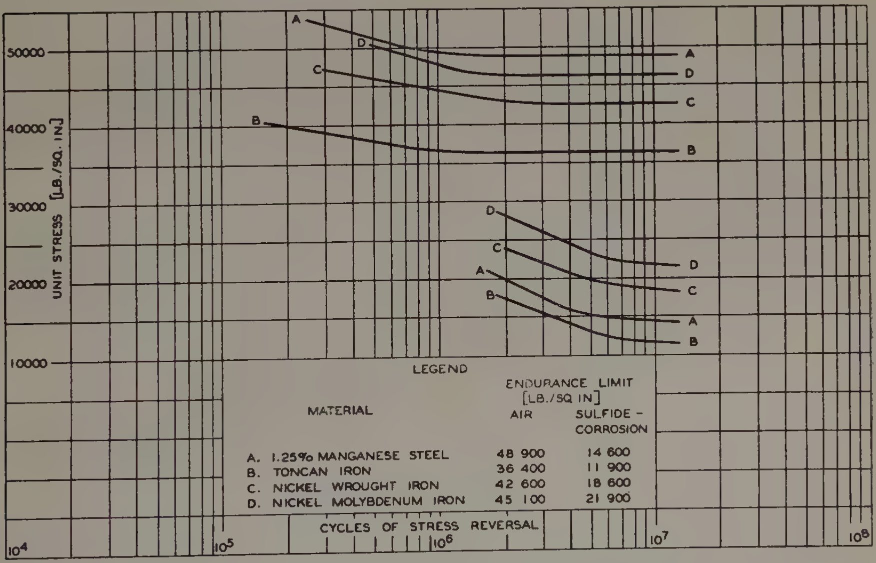

FIG. 2.—ENDURANCE PROPERTIES OF SUCKER-ROD MATERIALS IN AIR AND SULFIDE CORROSION-FATIGUE.

than under a similar degree of overstressing in noncorrosive conditions. Therefore, the selection of a material must take into account the ratio of stresses imposed by the given operating conditions to the respective endurance limit as well as the index value. For example, it would be unwise to select wrought iron for service in a well where the stresses exceed 30,000 lb. per sq. in., even though its index value is comparatively high; much more economical service would be obtained from one of the materials with higher sulfide endurance limit even at a greater cost. Experience indicates that greatest freedom from failures will be obtained when the ratio of operating stresses to endurance limit is less than 1.5.

A similar method for classification of materials could, if time permitted, be described for nonsulfide corrosive service, but in this connection it should be noted that, since the corresponding endurance limits are higher, the optimum yield point is higher. It is in this type of service, therefore, that the less expensive materials of higher strength can be used with economy.

TABLE 8.—*Classification of Sucker-rod Materials According to Service Conditions*

<table>
<tr><th colspan="6">Type of Service</th></tr>
<tr><th colspan="2" rowspan="2">Noncorrosive</th><th colspan="4">Corrosive</th></tr>
<tr><th colspan="2">Nonsulfide</th><th colspan="2">Sulfide</th></tr>
<tr><th colspan="2">Light → Heavy</th><th colspan="2">Light → Heavy</th><th colspan="2">Light → Heavy</th></tr>
<tr><td>S.A.E. 1035</td><td>S.A.E. 1050, heat-treated</td><td>S.A.E. 1035</td><td>1.25 per cent manganese</td><td>1.25 per cent manganese</td><td>Nickel wrought iron</td></tr>
<tr><td>S.A.E. 1045</td><td>S.A.E. 3130</td><td>S.A.E. 1045</td><td>1.75 per cent manganese</td><td>Wrought iron</td><td>Nickel iron</td></tr>
<tr><td></td><td>S.A.E. 4130, heat-treated</td><td>Toncan iron</td><td>S.A.E. 3130</td><td>S.A.E. 4615</td><td>Nickel molybdenum iron</td></tr>
<tr><td></td><td>1.25 per cent manganese</td><td>Wrought iron</td><td></td><td colspan="2">1.25 per cent manganese</td></tr>
<tr><td></td><td>1.75 per cent manganese</td><td colspan="2">Wrought iron</td><td colspan="2">S.A.E. 4615</td></tr>
<tr><td colspan="2">1.25 per cent manganese</td><td></td><td></td><td colspan="2">Wrought iron</td></tr>
</table>

SELECTION OF MATERIALS

The opinion was expressed earlier that not more than four different types of sucker rods were needed to successfully satisfy all demands of current operating conditions. At least three times this number are available. It will require one or two years of operating experience to indicate definitely from an economic standpoint which four materials are most worthy of retention. The uncertainty at present is almost entirely concerned with materials for heavy pumping service in sulfide fields and it is doubtful whether the material of greatest ultimate economy has even yet advanced to the stage of field tests. Four materials, all alloys of nickel, are now giving improved service under these conditions, but entirely too little attention has been given to alloying materials other than the comparatively expensive nickel.

A classification of the 13 materials now being used, according to conditions of service, is given in Table 8. This classification, which expresses the opinions only of the authors, takes into account the physical properties of the materials that have been discussed.

Acknowledgments

The authors wish to express appreciation to Dr. P. D. Foote, Executive Vice President of the Gulf Research & Development Corporation, for permission to publish this article, and to Dr. M. Muskat and Mr. L. W. Vollmer, of the same organization, for suggestions in the preparation of the manuscript.

DISCUSSION

(P. E. McKinney presiding)

H. H. Power,* Tulsa, Okla.—What is the authors' opinion regarding the endurance limit of the 1.25 per cent manganese steel in the normalized as compared with the unnormalized condition?

C. N. Bowers.—Our tests have shown practically no difference in endurance limits of this grade of steel in the normalized and unnormalized conditions under either corrosive or noncorrosive conditions. We have made some embrittlement tests on tensile specimens of this material in both conditions and while the normalizing seemed to have increased the susceptibility to embrittlement, the tests were too few to be conclusive. We expect to supplement this work in the future with a more extensive program, and I am sure that some definite information will be obtained a little later on.

D. R. Dale,† Toledo, Ohio.—The sucker-rod problem is not only fascinating; it is baffling. This paper has given much information that no doubt would reduce the number of failures in service if followed in the field.

It was noticeable in the endurance limits given for the various materials under different conditions of corrosion-fatigue that the endurance limit under sulfide-corrosion limits with the best steel, that is, the one that showed the highest endurance limit, was roughly of the order of 22,000 lb. per sq. in. It has been stated that some of these peak loads run on the order of about 30,000 lb. per sq. in. Therefore, the materials that have been tried up to date fall about 25 per cent short of a desirable endurance limit for good service; that is, they do not have adequate sulfide endurance limits to begin with. This brings up the point that sucker-rod strings should be designed (I do not mean the designing of the rod itself) from the beginning of pumping operations. Consideration and thought should be given to the selection of material, and the string should be designed, by the use of proper plunger diameter and speed and stroke, to keep the maximum stress within the endurance limits of the material. Failure to do this is one of the reasons, I think, for so many sucker-rod failures.

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† Chemical Engineer, The S. M. Jones Co.

Another point that was not mentioned is the relation of impact values to field results. So far materials that have given good service have had comparatively low impact values. Materials that have not given such good service have had sometimes high and sometimes low impact values, and, as Dr. Wescott and Mr. Bowers have stated, there does not seem to be any one way by which the impact value of a sucker rod can be correlated with service. At present, I think it is not known whether a good sucker rod should have certain chemical reactions or certain physical properties. I think that within the next year these points should be cleared up.

I was sorry to see that a formula for evaluating sucker-rod service was injected into the paper. The question of a formula for evaluating sucker rods has come up before a section of the A.P.I. for years, and I do not believe that we can ever arrive at a formula that will evaluate the service of sucker rods. The variables are too numerous and ponderous to be calculated. This formula, however, could be used as a criterion of service expected, say in a new field. If the fluid, operating conditions and required production are known, such a formula might be used as a means of selecting the right material, but I believe that danger lies in the use of such a formula, in that if results are not as expected blame may be laid upon the material rather than upon the formula. In this formula the expressions seem to me to be entirely too empirical, in that numerous unknown quantities, such as instantaneous peak loads and stress concentration due to notch affects, cannot be exactly calculated, but nevertheless have an important influence on the results. I hope that operators in general will not try to use this formula as a means of evaluating sucker-rod service.

B. B. Wescott.—The formula is purely arbitrary and represents what might be called a first approximation in an attempt to evaluate steel by consideration of the more important physical properties that seem to have a bearing on sucker-rod service. I agree with Mr. Dale that it is of general and not specific nature and is intended primarily to assist in making an economical selection of materials for service in new fields under conditions that are not entirely known, and to provide a method by which the suitability of new steels for this kind of service may be judged approximately.

K. H. Read,* Bethlehem, Pa.—I believe Mr. Bowers mentioned four materials that have been found satisfactory for sucker rods. I understood him to say that they all contained nickel, but I do not recall the other alloys.

B. B. Wescott.—I think Mr. Bowers said that it was predicted that four materials would eventually be found to be a sufficient variety to satisfy all operating conditions, and that these materials would be designed for noncorrosive service, corrosive nonsulfide service, and corrosive sulfide service. There was no prediction of just what these materials would be. Some 13 types of steel are being manufactured into sucker rods at the present time. This large number is confusing to the purchaser and is uneconomical for the sucker-rod manufacturers because of the large stocks that must be carried. It is predicted that four types will be sufficient to meet all demands of the different operating conditions.

E. G. Oppenheim,† Trenton, N. J.—What proportion of wells are considered moderately corrosive and very corrosive, including the hydrogen sulfide wells that are pumped?

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* Bethlehem Steel Co.

† Research Engineer, John A. Roebling Sons Co.

B. B. Wescott.—In general, any well that is of a sulfide nature and producing water at the same time gives more or less trouble from corrosion. If such a well is not making water, there will be no extensive corrosion difficulties.

E. G. Oppenheim.—May I modify that a bit? I should like to learn about what percentage of wells would be considered moderately corrosive as compared with all the wells.

B. B. Wescott.—That is difficult to answer. In general, all of the wells in Kansas, most of the wells in West Texas, and probably 10 to 15 per cent of the wells in the Gulf Coast district, might be considered severely corrosive. Practically all Kansas and West Texas production is sulfide. However, many of the West Texas wells are not troublesome at present, because of proration.

R. L. Duff,* Elizabeth, N. J.—What proof is there that hydrogen sulfide attack is intercrystalline?

B. B. Wescott.—The main evidence is that failures occur suddenly: the length of time of exposure of steel to hydrogen sulfide required to embrittle it is so short that it is hard to believe that the action could be anything else.

R. L. Duff.—If it is intercrystalline, carbon is eliminated as methane; and another thing, this material can be reconditioned by temperature. If it cannot be reconditioned, it is a chemical reaction and not a mechanical absorption.

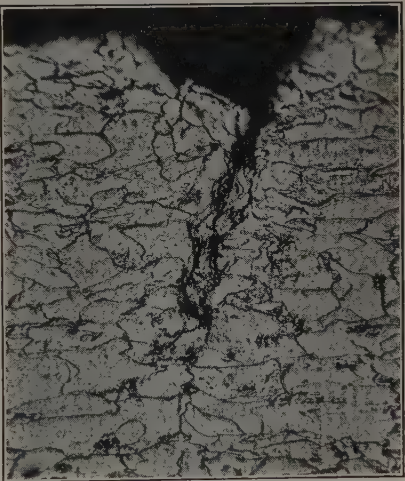

Fig. 3.—Intercrystalline crack in steel resulting from embrittlement by hydrogen sulfide. ×250.

B. B. Wescott.—The embrittlement action is physical if intercrystalline, but if it is intracrystalline it must be chemical.

R. L. Duff.—I do not agree with you there.

B. B. Wescott.—Nascent hydrogen is readily adsorbed by steel. If the embrittlement were chemical in nature it is hard to understand how it could take place so rapidly at ordinary temperatures or how the steel could recover nearly all its ductility on standing or by moderate baking.

R. L. Duff.—Most attack by hydrogen is corrected by temperature as, for instance, caustic embrittlement can be reconditioned by possibly 400° or 500° F. Also, some of the higher alloys being attacked by hydrogen through adsorption can also be reconditioned by temperature. Possibly sunlight in itself will recondition your sucker rods in time. I still cannot see that it is a chemical attack.

B. B. Wescott.—I do not believe embrittlement is a chemical reaction, although the nascent hydrogen responsible for the embrittlement is generated by a chemical reaction.

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* Metallurgical Technologist, Standard Oil Development Co.

R. L. Duff.—If it is intercrystalline I cannot see that it can be anything else but chemical. You have decreased your carbon content. A chemical analysis would show a loss of carbon content, if the attack were chemical. The microscope also would show a chemical attack. Also, in going into this subject of hydrogen attack of steels, I think I have learned that it takes temperature to cause chemical attack of plain carbon steel.

B. B. Wescott.—No evidence was included in the paper to indicate whether embrittlement was intercrystalline or intracrystalline in nature since, it did not occur to the authors that any one familiar with hydrogen sulfide embrittlement of steel would doubt that it was intercrystalline. Fig. 3 was prepared to dissipate any doubt that might remain. It is a photomicrograph of a crack resulting from hydrogen sulfide embrittlement and it clearly shows that the fracture is completely intercrystalline.

Chapter III. Stabilization

(New York Meeting, February, 1934)

On Feb. 22, 1934, the A.I.M.E. Petroleum Division Stabilization Committee conducted a symposium in New York City on stabilization of the oil industry. Among those taking active part in the discussion were Messrs. Sidney Swensrud, Joseph E. Pogue, W. S. Farish, J. B. Umpleby, H. D. Wilde, W. E. Wrather, Northcutt Ely, E. L. DeGolyer, E. A. Stephenson, Earl Oliver, Amos L. Beaty, Nathan R. Margold, Henry M. Bates and Roscoe Pound. Because of the volume of this discussion it was withheld from publication in the 1934 annual petroleum volume with the expectation that a special volume on Petroleum Stabilization would be issued during the year in which the entire discussion could be published. That was not done. The addresses of Dean Bates and Dean Pound, dealing as they do with broad principles of Constitutional law, are as timely now as they were when delivered one year ago and are reproduced herein for their bearing on current legislative proposals.

Some Constitutional Aspects of the Oil Problem

By Henry M. Bates, Dean of Michigan Law School

Mr. Chairman and Gentlemen: I accepted your Chairman's invitation to speak to a group of experts in this field with the greatest hesitation, because I know little or nothing about it. Certainly I can make no detailed suggestions, or suggest planning along very definite lines. You cannot do that sort of thing in a vacuum, and as I have suggested, my knowledge of the whole oil problem is next to nothing. It is possible that as a student of our public law, constitutional law particularly, for a number of years, I have acquired a perspective that may enable me to offer, for what they are worth, some general thoughts on these problems.

I think that nothing in the whole field of law requires more definitely and clearly the functional approach than does the problem of a sound legal solution of the difficulties of the oil and gas industry. The industry is dealing with substances that are peculiar, and one must know how those substances act and what has been the history of the industry, to undertake to make anything like specific suggestions. I certainly am not qualified.

This morning I had the pleasure of hearing a paper by Judge Beaty[1], which made certain suggestions which I want to say something about, before I read a very hastily prepared paper. It was clearly brought out in his paper that the difficulties that the oil industry is encountering in the legal field cluster very largely about two or three governmental and legal principles or concepts.

In the first place, there are some unfortunate notions about the protection supposed to be thrown about property by the due process clauses in federal and state constitutions, which have stood in the way of dealing with oil, in the past, as intelligence required it should be dealt with. Then there is the division of powers of government, in our country, between the Federal Government and the state governments, and that cuts across the control which Congress has over industry and commerce.

Finally, among the three things that I think of in relation to Judge Beaty's paper is the difficult matter of the distribution of governmental powers to the legislative, executive, and judicial departments.

Now as to notions of property, I suppose that while the human race has always been acquisitive and has desired possessions, property as we know it today is relatively a late development in our law. It is not an absolute, it is not a God-given, concept. The term is one that we use to describe what we call rights, a group of rights acquired under certain conditions. It is not a rigid, enduring thing in the form in which it originated.

In the present period we see some of the earlier conceptions about property subjected to great pressure and more or less disintegrating influences, with growing restraints upon property rights.

More specifically, what do the due process of law clauses in the Fifth and Fourteenth Amendments to the Federal Constitution, and in all state constitutions, have to say in relation to property, especially in protecting it, if that be the proper word, from some sort of regulation or supervision by government?

When I first began to study law, what was stereotyped out to almost every student was that ownership was absolute and that if it were land you were considering, you owned it from the center of the earth to the sky and nobody could interfere with your using that property precisely as you might wish to use it, as long as you did not specifically injure others.

Somehow or other, by a species of reasoning which I have never been able to follow, it has been supposed that the due process clause protects that early conception, that primitive conception of property and its management.

Well, what is due process of law? In the first place, it is not a rule of law in any proper sense of the words used. I think of it, at least in relation to such subjects as this, as a standard of governmental action in relation to citizens and the rights which they are supposed to have.

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[1] A. L. Beaty: Quotas in Commerce. *Oil & Gas Jul.* (March 1, 1934).

We don't know how old the concept is. Of course, every school boy knows that the term or an equivalent of it was used in Magna Charta. But that term was then so definitely crystallized that the concept must have been far older. I think I see indications of it in an Egyptian code which most law teachers know a little about—a code that was developed about 2550 B.C. You find equivalent concepts of one sort or another in almost every civilized nation.

It is utterly absurd to suppose that the due process clause, properly interpreted, can interpose obstacles, barriers to reasonable and just regulation of what we call property rights, simply because they are novel or because no exact precedent can be found, and because they do to some extent impinge upon complete and absolute management and control by the so-called owner.

We have been living in a period in which, because of the conditions of this country, with its rapid growth, its conquest of a great continent and all that, the need of giving initiative every chance in the world was paramount and overemphasis upon the acquisition of wealth was very great. And during that period the due process clause has been given a constricted and distorted meaning and has been applied in an artificial way to many situations.

I recall a case in which the due process clause was urged as preventing a state from regulating the sizes of loaves of bread sold by bakers. It may be very ridiculous, very unnecessary, to regulate the sizes of loaves of bread, but to suppose that a governmental standard or policy of the age and scope of the due process concept would be rationally applied to a meticulous proposal of that sort seems to be quite absurd. The case got clear to the Supreme Court of the United States, after many vicissitudes, and the idea was rejected by the court. But many cases could be cited if time permitted, in which things not quite so absurd, so extreme, as the argument of counsel in that case, were really listened to and accepted by the court.

To my way of thinking, the due process clause does not prevent the adoption of methods and regulations that are reasonable, that work justice as among owners of a particular kind of property, where, as is especially true in this case, the public welfare seems to require such methods and regulations. There is plenty of Supreme Court authority for these views.

As to the distribution of powers of government between nation and states, it is not true that there are certain definite specific powers which wholly and absolutely belong to the states as such and concerning which the Federal Government has no power. For example, the power to legislate or make laws in relation to the holding of real property is one of those powers properly exercised by the states and a power which, of course, falls among those which have been reserved to the state. And yet it has been shown that the Federal Government may properly exercise important control over real property in the states. Treaties have made provisions contrary to the laws of particular states, and the Supreme Court has sustained the treaties. Thus there is a somewhat indefinite, somewhat expansible, area in which the Federal Government may intervene in relation to law relating to property—as intensely a local thing as one can call to mind.

In other words, putting it briefly, as our life changes, as our occupations become more intricate and as they become more integrated into each other, there are produced conditions not dreamed of in 1787, which the states as such cannot handle effectively, sometimes not at all. Conditions arise which bring many subjects ordinarily passed upon and controlled by the states within the range of existing Federal powers. It is not that new Federal powers have been created; it is not that powers have been taken away from the states. It is simply that a life strikingly different from the life of 1787 has produced a great many situations, possibly through integration of one thing into another, and one function into another, which not only require but which constitutionally justify Federal activity.

Now, of course, that is peculiarly true about the law relating to interstate commerce, and Judge Beaty this morning made it very clear how in relation to oil, particularly matters ordinarily exclusively local, by virtue of integration into other processes, become so associated with transportation and business in other states as to become properly within the interstate commerce powers of Congress.

Perhaps it is necessary to say not that new conditions have given the Federal Government any authority over production as distinguished from commerce, but that commerce, under modern conditions, reaching back into production, has integrated certain aspects of that production with itself so definitely, so clearly, that to make control of commerce effective the authority of Congress in that regard is plenary. Congress must have the authority, and constitutionally does have it, to take whatever steps within reason may be necessary to regulate for commercial ends business of this character.

In all of the problems thus suggested the question of delegation of power, legislative power usually, is pretty apt to arise. It has arisen definitely in relation to the oil industry. Delegation is a method utilized by the N.R.A. in the codes for certain purposes, and a question is, how far can delegation go? There, again, I think that today we have to rid ourselves of certain early acquired notions about the distribution of powers of government into the legislative, executive, and judicial departments. We have to reconsider, at least, the maxim that a delegated power cannot be delegated. Why do we have to reconsider? Why is there some question about the one hundred per cent validity of these maxims?

Well, in the first place, we know that there never was complete separation of the three powers of government, anywhere on the face of the earth, and that we adopted the theory with fervor and put it into our Constitution upon a mistaken notion, largely. As I have indicated, it is impossible to separate these powers completely, even as a matter of abstract definition. As a matter of practice, it cannot be accomplished. There has always been some crossing of lines.

A young friend of mine has just written a thesis on "The Development of Administrative Law in Canada." And it shows that Canada and our own Colonies, long before 1787, often merged, to a considerable extent, two of these powers in the hands of administrative officers or tribunals, as we should call them today.

Now with those suggestions made, I shall, with some hesitation, proceed to read at least a part of this paper.

The purpose of this paper is to refer briefly to some of the important features of our governmental structure and to some of the broad standards and principles of our legal system, which bear upon the ownership and production of oil and gas. The law relating to what is called the "oil problem" has been discussed exhaustively and from every point of view, by numerous writers and speakers during the last few years. It would, therefore, be superfluous to present, on this occasion, a detailed discussion of the legislative acts, court decisions and administrative regulations relating to this problem.

In the whole range of legal developments there is, I believe, no other situation so dramatically illustrative of the vital importance of a correct understanding of the fact situation and of the formation of a sound theory concerning it as is the present plight of the oil industry.

(Interpolation No. 1) This matter has been discussed so exhaustively by many writers and speakers, some of whom are present, that it would be quite absurd for me to go into a detailed discussion of the legal problem. Moreover, it is my belief that development in your field is not going to come by meticulous following of precedents and the consideration of fine distinctions. It is going to come by taking into account some of the broad developments and by dealing with your subject broadly.

(Continuation of paper) The infinite harm to the public welfare, and the serious injury inflicted upon legitimate private interests which may be caused by erroneous fact assumptions and false deductions of law drawn therefrom are now being demonstrated with tragic intensity in the oil and gas situation. The problem presented by existing demoralized conditions in the production of petroleum and its derivatives, is one of vital importance, not only to the owners and operators of oil wells and to the oil industry as a whole, but not less to the entire nation.

It is well known that the oil industry is a very new one, scarcely seventy-five years of age. But despite its rapid development and its exploitation of wealth fabulously great, its troubles have more than kept pace with its growth and today the industry's condition suggests the plight of the "poor little rich girl." It is calamitous that when the earliest oil controversies were brought into Pennsylvania and other courts little was known about the nature of oil and gas, of their interaction upon each other, or of the effect upon the entire oil field produced by the operation of wells therein.

But it was natural that in the beginning courts should have seized upon analogies in the law of real property to guide them to a determination of the issues presented. Some judges compared oil and gas to hard and stationary minerals in the soil, such as coal and iron, but of course it was known even then that oil and gas did not behave like hard minerals. Behavior perhaps may not properly be attributed to inanimate objects, but the volatile nature of oil and gas suggested behavior, and earlier Pennsylvania courts had thought that they might be likened, for legal purposes, to wild animals, not subject to ownership in place but belonging to him who first subjected them to possession. They were also likened to percolating underground waters, but these naive theories confined within the strait-jacket of the common law, led to much the same results—results most unfortunate to individuals and to the public.

The adoption of these erroneous theories has produced enormous losses and waste of valuable natural resources, which, though existing in abundant quantity, are nevertheless definitely exhaustible resources, vital perhaps to national defense in time of war and absolutely essential to industry, commerce and transportation, as now conducted. The unrestricted exploitation of these natural resources that followed the realization of the riches which they produced has naturally attracted all kinds of men, the bad among the good, and set in motion a feverish and ruthless pursuit of this wealth in the ground, that has led to injustice among men scarcely less harmful than the great waste of these gifts of nature. Fortunately, however, the appalling waste which followed the ignorant and ruthless pursuit of fortunes to be pumped from the earth, particularly in recent years, has occupied the attention and enlisted the services of thoughtful and able men, some of whom, at least, have been as conscious of the public stake in this matter as of the private interests involved. The industry and the country unquestionably owe a debt of gratitude to some of these men who have rendered yeoman service in the difficult and complicated task of uprooting erroneous beliefs and theories and substituting enlightened plans for operation and production based upon ascertained facts and scientific principles.

The abuses and evils in the production of oil, which leaders in the industry itself are endeavoring to cure, are too well known to justify enlargement upon them here. The effect of early court decisions based upon the erroneous theories heretofore referred to, was to make legal the pumping of all of the oil and gas possible from every man's well. Thus in the larger fields one producer might, and in fact often did, pump vast quantities of oil and gas underlying lands belonging to or controlled by other producers. This in itself violates any sane theory of property rights. It has induced a feverish scramble to get all that each owner can pump regardless of whose land it underlies, and in order to prevent owners of adjacent lands from securing the oil lying therein, the mad scramble further resulted in the waste of vast quantities of gas which were allowed to escape in the air, a result not only disastrous in itself but which produced even greater losses, in that the released gas was no longer available for propelling the oil toward the surface. The losses thus caused unquestionably mount into the billions of dollars and constitute the most reckless, extravagant waste of natural resources that even the American people have been guilty of. Moreover, this mad and greedy race for wealth has made it impossible in this country to adopt intelligent and effective methods of production, the cost of which has thus been made greatly and unnecessarily high. This high cost of production makes it impossible for American producers to compete with the British and other European producers owning oil rights in Persia, Turkey, and other countries.

Finally, those methods of production and distribution which have heretofore prevailed in this country have taken no account of the so-called economic laws of supply and demand, of present or of future needs, but have dumped upon an already saturated market vast quantities of petroleum, thus often depressing the market prices far below the cost of production. The American public will in the future pay a heavy price for such advantage as it has obtained from buying oil below cost during this period of unintelligent and unjust distributive scramble.

The direction that remedial steps must take is fairly obvious and several such plans have been outlined by the industry itself and by others. It is unnecessary for me to describe here proration and unit operation. The details of these and other suggested methods of production and of determining distributive shares are far better understood by members of this Institute than by me, but perhaps it may be pertinent to say that, from the lawyer's viewpoint, the most strongly supported proposals look to the establishment of certain corrective measures, among which are the following: (1) the allotment to each producer of that proportion of the total oil and gas content of the field which lies beneath the land he owns or controls.

(Interpolation No. 2) I am not sufficiently conversant with the details of that to say whether other factors are taken into consideration to determine the distributive share, but as I understand it that is the principal measure used.

(Continuation of paper) We are told on good authority that as an engineering matter it is quite possible to ascertain with reasonable accuracy the share of oil to which each producer is justly entitled on this basis. (2) As the proration plan in itself is inadequate to produce desired results for reasons well known, the idea of unit operation was developed and worked out in considerable detail. This aims not only at allocating to each producer his just share, but also it makes possible scientific and economic methods of production. Furthermore, unit operation would tend to secure production at times, places and in the quantities reasonably calculated to adequately supply the market with prices just to the consumer as well as to the producer, and thus to conserve these great natural resources.

In 1927 the Federal Oil Conservation Board created, with the cooperation of the American Bar Association, a committee of nine to consider plans to promote the conservation of petroleum and natural gas. This committee consisted of three members of the American Bar Association, three representatives of the oil industry and three officers of the United States Government. After prolonged consideration, during which public hearings, open to all who were interested, were held at Washington, the committee made a report to the Federal Oil Conservation Board which contained the following recommendations:

1. Federal legislation which shall (*a*) unequivocally declare that agreements for the cooperative development and operation of single pools are not in violation of the Federal antitrust laws, and (b) permit, under suitable safeguards, the making, in times of overproduction, of agreements between oil producers for the curtailment of production. . . .
2. Similar legislation by the various oil-producing states.
3. Immediate further study into the matter of the waste of natural gas, in order that legislation may be formulated which will forbid such waste as fully as may be done without working injustice and unreasonable hardship.

With reference to the proposed state legislation, the committee, it will be noted, recommended further study of the underlying problems before the drafting of a proposed bill. The committee indicated, however, a strong belief that there should be cooperative development of oil fields by their owners and operators. The committee did not suggest compulsory unit operation. The committee's report still seems to me to be based upon known facts and to embody sound conclusions and recommendations. But, though I was a member of the committee, I have always felt that its report fell short in some particulars of making recommendations that might effectively remove fundamental evils from the present situation. The report was, of course, a compromise to some extent, of conflicting views of some members of the committee, but to a far greater extent it was a compromise between opinions as to what was desirable, held by all members of the committee, and their conclusions as to what it was practicable and wise to ask for at that particular time. Undoubtedly, the Federal Oil Conservation Board would have approved, in principle, of more drastic regulation of the production of oil than that recommended by the Committee's report. However, it was felt by all that with the political campaign approaching Congress and state legislatures would refuse to consider very material departures from existing methods of control.

(Interpolation No. 3) The presidential campaign was not so very far away and whatever the Federal Oil Conservation Board might have been willing to do, if it had the power, even its recommendations apparently were too strong for Congress to care to deal with.

(Continuation of paper) It was, and still is, my belief that compulsory unit production is not forbidden by constitutional provisions, federal or state, but on the contrary, is within the range of our governmental powers and is within the spirit and principle of the common law, as shown by many decided cases.

All kinds of legal objections have, of course, been urged to every progressive proposal of a solution of the problems. The early decisions already alluded to here, it was argued, had established the law for all time as making legally impossible any interference with or regulation of owners in dealing with their property as they liked. But with the advance of scientific understanding of the nature and action of oil and gas, the theories underlying these early decisions were bound to yield, as indeed they already have, in most of the jurisdictions of the country. Once the facts were known, it has been easy to persuade most courts that the peculiar fugacious character of oil and gas and the dynamic character of gas in propelling oil toward the surface, made the supposed analogy to wild animals not only grotesquely absurd, but resulted in injustice violative of the spirit of the common law of property and productive of disastrous losses to all concerned.

However, it was soon demonstrated that the substitution of sound methods of production could not be left to the owners of oil properties. Some degree of compulsory cooperation was clearly necessary and this meant governmental supervision and control. The earlier efforts to secure such governmental action were addressed to the several states, but here again greed and ignorance combined to prevent proper and just allotments of production as between the states. Some kind of federal action was obviously desirable. Against all efforts to secure this governmental cooperation with and supervision of oil production, opponents of effective regulation have persistently urged narrow and antiquated theories of the law of property, the due process clauses of the state and Federal constitutions, historically unsound versions of the reserved powers of the states, and unrealistic concepts of the limits of the interstate commerce power of Congress.

(Interpolation No. 4) Just a word thrown in about the reserve powers and the restrictions which the reservation puts upon the exercise of the commerce power. Have we not all got far enough away from the early period of our history to discuss objectively so-called state sovereignty and so-called state rights and so-called national powers? Well, when a state gets into action, even some pretty well to the south, and I am not forgetful of the fact that in New England there was a period when state rights were shrieked as loudly as anywhere in the country and secession was suggested before South Carolina began to move—so if there would seem to be any criticism on what I say about those conceptions, it is certainly not directed to any section of the country. It was inevitable, of course, in view of our history that we should come into our present government with the conception that sovereignty was divided piecemeal. You cannot divide sovereignty into pieces as if it were pie; it does not yield to that sort of action. There are interrelations which no knife can cut.

I was interested to see that not very long ago the Attorney General of Arizona in a petition filed in the United States Supreme Court in relation to the construction of a dam, which many of you no doubt know about far more than I do, spoke of the quasi-sovereignty of the State of Arizona. And he complained that the proposed dam was an invasion of that "*quasi*-sovereignty." That indicated some advance in objective thinking about that controversial question. The grant of federal powers was in such general terms and over such matters that their gradual application to new things was bound to result in such situations at least as the Attorney General of Arizona complained about.

(Continuation of paper) Several papers, read before this and other associations interested in the problem, have dealt rather extensively with the common law background for governmental regulation of the kinds of property, and functions involved in oil production, so that it seems appropriate here to indicate briefly the characteristics of this property which make regulation feasible, if not necessary.

In an important case decided by the Supreme Court of the United States (*Head* v. *Mgg. Co.*, 113 U.S. 9) the court declared that "when property in which several persons have a common interest cannot be fully and beneficially enjoyed in its existing condition the law often provides a way in which they may compel one another to submit to measures necessary to secure its beneficial enjoyment, making equitable compensation to any whose control of, or interest in the property, is thereby modified." The opinion goes on to refer to many such situations as the tenants in common in land, who may be compelled to submit to a partition if the land cannot be equally divided, to water rights held in common, which may be the subject of partition in equity and other instances. The principle was recognized as long ago as the time of Lord Coke, and is the basis of the numerous mill acts in New England, all of which compel the submission of individual rights to the common interests and rights of all concerned. Other examples may be taken from the maritime law and from the statutes relating to irrigation and drainage. In truth, the principle is well recognized and has been applied to many situations. In none of these older cases was the need of compulsory cooperation as obvious and as important as it is in relation to the production of oil. Not only is the necessity for compulsory cooperation greater and more demonstrable in the case of oil producers than in any other situations just referred to, but the public interest, both national and state, is infinitely greater. It is well known to all that the principle here contended for was essentially conceded in the case of *Ohio Oil Company* v. *Indiana*, 177 U.S. 190. The Supreme Court in that case chose to base its decision principally upon the private interests of the owners and the necessity of doing justice between them. It might well, however, have relied chiefly, if not exclusively, upon the importance of conservation to the public welfare and national needs. Reference will be made here to only one more case, that of *Marrs.* v. *The City of Oxford*, 32 Fed. (2) 134, in which the United States Circuit of Appeals, sustaining an ordinance of the city of Oxford in Kansas, set up at least a rudimentary scheme of compulsory unit operation. It is so clear that the just interests of all concerned would be conserved by the application of such a plan, and their ultimate profits increased thereby, that it seems reasonably certain that courts will sustain the application of the principle in proper cases, especially in view of the great stake which the public has in the matter.

(Interpolation No. 5) The court in its opinion cites a large number of cases, quotes Littleton and from some early English cases. The opinion refers to such somewhat analogous situations as those of tenants upon the land, water rights which may be the subject of petition in equity, cargoes on ships and control and repair and management and chartering of ships themselves. Anyone familiar with common law can add many other examples. The principle, as I have said, was at least as old as Coke and back of him Littleton, and is the basis of the numerous mill acts in New England.

(Continuation of paper) The report of the committee of nine, already referred to, failed to make any recommendation of importance in regard to the possible exercise of Federal control. It was then, and it is now, my belief that the possibilities of Federal supervision have scarcely been explored, and that existing conditions and tendencies demand Federal action in the matter. We have had unpleasant but convincing evidence of the inability or unwillingness of the states to act cooperatively in the matter. The conflicts which have ensued have nullified the quota systems and have deprived unit operation, where it has been voluntarily put into effect, of much of the beneficial influence which it otherwise would have had. Moreover the exclusive control given to Congress of all interstate commerce requiring uniformity of treatment, and the presence of the Sherman anti-trust law on our statute books, make participation by the Federal Government essential if the best results are to be obtained.

(Interpolation No. 6) And it seems to me that however imperfect it may be in detail and however badly it may be now administered, the utilization, which that Act undertakes to accomplish, of the help of the trades and occupations and so on, affected industries, is a wise one. We at least, in my opinion, have seen the Sherman anti-trust law where it was no doubt of some good in putting a stop upon development of the trust and merger fever so strong in the nineties, and not dead yet by a good deal. We have seen that scheme fail because it is abundantly clear that the legislature itself, with the fortuitous recourse to the courts which litigants determine upon, is not an adequate system for dealing with a continuing function which is all the time requiring consideration of the specific facts in specific situations. Therefore, the utilization of the industries themselves to undertake part of that work, it seems to me, is highly to be commended.

(Continuation of paper) Several provisions in the United States Constitution might be resorted to for the sources of power which may be exercised to secure an adequate and comprehensive regulation of the oil industry. Interstate pipe lines offer an obvious mechanism to which federal power may be directed effectively to secure desirable results. To such suggestions it has, of course, been objected that the pumping and refining of oil do not constitute commerce, and that they are functions exclusively subject to state control. There are some early decisions which support this view, for example, those in the case of *U.S.* v. *Knight,* 156 U.S., and *Hammer* v. *Dagenhard,* 247 U.S. 251. Both cases have been subjected to just criticism and not much remains of the Knight case. In any event neither case should be held controlling in the proposal for the unit operation.

On the other hand, there are numerous recent cases holding in effect that, so far as it may be necessary to make congressional control of interstate commerce effective, Congress does possess the power to make proper and reasonable regulations in regard to property, commerce, accounting and related undertakings and functions. I need refer only to the Shreveport Rate Cases, 234 U.S. 342, *McDermott* v. *Wisconsin,* 228 U.S. 115, to indicate the line of reasoning adopted by the Supreme Court.

(Interpolation No. 7) I should like to say just a word about the case of *U.S.* v. *Knight,* which has emphasized the distinction between production and commerce, and which I think has made it very difficult for us to make advances in intelligent regulation of merged functions. I have always thought that the background of the sugar-refining industry, the facts were not presented to the Court on that occasion and that had they been presented it would have been seen that under the conditions then existing the refining of sugar and commerce in sugar were so integrated and so almost merged—well, I would rather term it not merged—were so integrated that it was impossible to regulate the commerce part without touching upon so-called production in the refining of sugar. I feel that though the Court has never overruled in terms of that case, it has not been guided by it in several recent decisions, but on the contrary has rather disregarded some of the broad statements that the opinion contained.

(Continuation of paper) The truth is that today manufacture and other forms of production are so inseparably connected with, if not merged into, the whole commercial process that they cannot be realistically separated. It is easy to say that pumping oil or refining sugar are not in themselves commerce, but contemporary methods of doing business have, as a matter of fact, integrated these processes in a large proportion of the business of the country. The view of the matter thus briefly sketched is that taken by the N.I.R.A. and codes thereunder. Without meaning in any degree to prophesy that the courts will hold constitutional the N.I.R.A. plan in its entirety, it is nevertheless submitted that that feature of it which undertakes regulation, for control purposes, of the processes which do actually enter into and effect interstate commerce, is sound and finds adequate support in existing decisions of the courts. The spirit of the times is against artificial or fanciful interpretations or classifications. We are looking at life functionally, and are properly insisting upon realistic, as opposed to bad, metaphysical distinctions and catagories.

The war powers of the President and Congress undoubtedly may be exercised to conserve oil and gas, so important not only for the supporting industries of the country, but for the prosecution of war upon land, sea and air, but until this supply of oil is more definitely and demonstrably near to exhaustion, there would be little hope of Congress legislating in this regard to provide for future contingencies. Theoretically, this power is capable of great extension in the direction of conservation of national resources, but practically there would be little hope of obtaining important action at the present time.

The taxing power offers almost limitless possibilities. Thus the Supreme Court has sustained an alleged revenue act, the effect of which was to destroy an industry and thus to destroy revenue. These effects were anticipated and in truth desired. Nevertheless, the court sustained the statute, *McCray* v. *U.S.*, 195 U.S. 27. A more important case is that of *Veazsie Bank* v. *Fenno*, 81 Wall, 533. *Bailey* v. *Drexel Furniture Co.*, 259 U.S. 20, involved an effort by Congress to tax child labor out of existence. The stature was foredoomed to failure by reason of clumsy draftsmanship.

(Interpolation No. 8) In *Bailey* v. *Drexel Furniture Company*, the second child labor case based on the tax clause, the statute was held invalid, but I have always thought that that was foredoomed to failure by reason of clumsy draftsmanship as the bill was finally passed.

(Continuation of paper) Finally, the treaty-making power offers great possibilities. Article VI, Clause 2, of the Constitution provides that "this constitution and the laws of the United States which shall be made in pursuance thereof, and all treaties made, or which shall be made under the authority of the United States, shall be the supreme law of the land." Acting under authority of this clause, Congress enacted a measure for the protection of wild birds throughout the United States in order to make effective the provisions of the treaty which had been negotiated with Canada for that purpose. It had been held previously in two cases in the lower federal courts that Congress had no power, in the absence of treaty undertakings, to legislate with regard to the preservation of wild game. Whether those decisions were correct or not, the Supreme Court in *Missouri* v. *Holland*, 252 U.S. 416, held that the congressional act just referred to, passed in pursuance of treaty provisions, was valid. While the fact situations are not quite parallel, the method adopted in the bird-conservation measure is certainly applicable to the oil situation. True, wild birds are not private property and oil is, but oil is a peculiar kind of private property with some very troublesome characteristics, and such plans as unit operation are designed to, and would tend to, make more secure just private claims to oil in the earth. The effect of unit operation unquestionably would be to secure to each private owner a greater ultimate profit from the operation of his wells than would be possible under the unregulated productive processes of the past.

The events of the last few years, and the advent of the "New Deal," have led to the realization by most thoughtful men that, without what is called revolution, we are passing into a new era of our national life. Those events have demonstrated that modern life with its application of scientific knowledge to almost everything we do, the increase in population, the speeding up of transportation and communication, and the intricacies of modern productive and distributive processes, have made impossible, for the present at least, the successful operation of a distinctively *laissez faire* policy. The integration of our still rapidly increasing range of activities makes it impossible to successfully assert old and outworn concepts of absolute individual rights, in property or occupation. To make the best use of our resources for each and all, cooperation is necessary, and if it cannot be achieved by voluntary action the Government, in the interest of all of us, must intervene. There is nothing in the Constitution as I read it that prevents proper and reasonable regulation of the kinds here suggested. There are many who think otherwise, but most of those, it is believed, have accepted without question unnecessary and sometimes narrow interpretations placed upon constitutional provisions, such as the due process and commerce clauses, interpretations due to the peculiar beginning perhaps in the 1870's and continuing for four or five decades. Due process is not a rule of law in any proper sense. It is a broad and fundamental standard for governmental action and was never designed to prevent a people's government from taking reasonable steps to secure justice among individuals and to conserve the public welfare. Important national interests require that no narrow or distorted interpretations of broad constitutional provisions be interposed to defeat just and scientific measures which may be adopted to lift the oil industry from its present unhappy plight—a plight unjust and ruinous to honest producers and destructive of important public interests.

Some Constitutional Aspects of the Oil Problem

BY ROSCOE POUND, DEAN OF HARVARD LAW SCHOOL

Mr. Chairman and Gentlemen: I think I shall do best perhaps if I adopt the method which the colored clergyman stated he was to adopt when he said he would address his congregation somewhat promiscuously and then introduce edificationary remarks of a strictly extemporaneous character.

Questions, as I understood it, were put to Dean Bates and myself by Mr. Oliver in the very interesting statement that I listened to in the room above, with reference to the program which you are working out to meet the exigencies of this very difficult problem. We were asked whether a given program was mechanically possible, whether it was economically advisable, whether it was politically wise, and whether it was legally sound.

My revered preceptor in the law used to say, when questions were put to him, as to some questions which were covered by very clear and indubitable provisions of the statutes or were covered by a long and settled course of judicial decision in the highest court of the state, that he would give advice with professional profundity; but as to other questions that did not come within the clear purview of the statutes, or with respect to which the statutes were, as they often are, delightfully ambiguous, or with respect to which there had been no clear and settled course of decision, that he could do nothing more than make some suggestions with individual imbecility.

As to what is mechanically possible, as to what is from an economic standpoint advisable, as to what is politically wise, I can only speak with individual imbecility, and I do not know that my imbecility extends to such questions even. But I can speak with a certain amount of professional profundity with reference to what is legally sound. And it is to that part that I am going to address myself.

In the admirable statement that Dean Bates has made to us, he has pointed out that we have three difficulties from a legal standpoint to contend with in any such program as that with which you are concerned. We have to wrestle with the distribution of powers, both in nation and in state, among legislative, executive and judicial departments. We have to reckon with the distribution of the powers of government as between nation and state. Then, perhaps, in a way, most of all we have to wrestle with a requirement of reasonableness. Dean Bates has traced it back to Egypt. I have to speak, when you go back of Magna Charta, with individual imbecility. But I can say with professional profundity that from the time of Magna Charta, Englishmen, and in the modern world, the English-speaking world, have expected that the operations of government should conform to the exigencies of reason.

I do not know that any better statement of it was ever made than the one Lord Coke addressed to James I in a famous conference, attributed perhaps to Bracton, a great judge of the Thirteenth Century, that the king does not rule under any man, but under God and the law.

The idea is that the operations of government are to be carried on in a reasonable way—and that is what, fundamentally, all these requirements of distribution of powers and of due process of law come to; they are attempts to formulate a requirement, that what is done in the ordering of society by law shall be done in accordance with reason.

Let us look at each of these things a little more closely. I am going to deal in generalities because the specific part has been admirably and thoroughly dealt with by Dean Bates, and really there is no more that could be said about them. Let us look at the generalities a minute, because, after all, the letter killeth and the spirit giveth life, and it is the spirit in respect to which these things are applied and administered that counts in the long run and is going to count in these matters with which you are here concerned; especially in this distribution of powers between legislative, executive and judicial. So in my judgment, you are very much concerned in this problem because by and large you must look to administration to effect the purposes which you chiefly are likely to have in view.

In the theory of our polity, we have three coordinate, coequal powers. I do not know whether it ever occurred to you, but the truth is our polity is that of Seventeenth Century England. The Revolution of 1688 did not leave any mark upon our polity, because by 1700 our Colonial Legislatures had come into a consciousness of their powers and our ideals had become fixed as those of Seventeenth Century England. So that an American executive is, in reality, a Tudor or a Stuart king, and an

American president or governor rules with Congress or the Legislature, if he can, and in spite of them if he must.

As in Seventeenth Century England, king and parliament and court went their several ways, sometimes pulling apart, sometimes working together in all sorts of temporary and shifting combinations, so in our American polity, executive and legislative and courts sometimes pull apart in three different directions and like as not sometimes work together in temporary and shifting combinations. The problem then is unquestionably either to bring about a spirit of cooperation between these departments or to come to the centralization that is going on in Europe, because the somewhat differently organized departments of government there are not working together toward ends that require cooperative effort. But that is the realm of politics and I am not speaking about politics with professional profundity.

The interesting thing to me, however, is that while we have here in theory these three coordinate, coequal, independent departments, in the actualities of our public law sometimes one and sometimes the other has actually maintained a leadership.

In the earlier history of our institutions, unquestionably the leadership was in the legislature. The members of the legislature were the representatives of the people and they took that proposition literally. Legislatures in the earlier period of our polity did not hesitate to call the executive or the judiciary to account for their actions. The Stuart kings called the judges before them to account for their decisions. There was a time in our polity when state legislatures, if someone had been defeated in an action, would entertain a bill to grant the defeated litigant a new trial and would actually pass it. There was a time in one legislature at least in this country when, if someone applied to a judge to postpone his case and the judge would not postpone it, he could go to the legislature and get a bill postponing it to the next term of court. There was a time when Congress, as you remember, in the Tenure of Office Act that led to the impeachment of Andrew Johnson, undertook to tell the President about the composition of his Cabinet. The legislative branch of the government conceived that in a peculiar degree it represented the people, that it had a mandate from the sovereign people and spoke with the voice of the people. I suppose the last echoes of that legislative supremacy were heard in the speeches and opinions of the senators in the impeachment of Andrew Johnson.

There came a time after the Civil War when the leadership de facto, because there was not any leadership de jure, passed to the judiciary. If the legislature said it had a mandate from the people at the last election, the judges said they had a mandate from the Constitution. They spoke by the authority of that solemn act of the people in adopting a constitution and they spoke with the voice of that constitution.

What I think was immediately behind this judicial leadership in the period after the Civil War was the Fourteenth Amendment, which subjected state legislation to a test of reasonableness judicially applied.

In our polity, the great bulk of questions that have to do with relations of man with man in this country are within the purview of state legislation. When congressional legislation, under the Fifth Amendment, was subject to judicial scrutiny as to its reasonableness and state legislation, under the Fourteenth Amendment, was subjected to the scrutiny of the Federal judiciary as to its reasonableness, it followed for a time, since the judiciary had always in the English-speaking world had a power of scrutinizing the acts of the executive with respect to their legality, that everything that took place in government was potentially subject to a judicial scrutiny as to its reasonableness.

In the present century, it is pretty evident that another shift is taking place. It is quite as evident that today *de facto* leadership is in the executive and it is not hard to see why. One of the great problems in the crowded world of today is individualization of application; to have precepts, rules, standards, applied with reference to the circumstances of individual cases which vary infinitely in the complex life of today. That individualization is something to which legislative and judicial action are ill adapted.

But, again, it is important in the world of today, with the economic unification of the country, with the changes in transportation, the changes in transmission of intelligence, the necessity of getting things done speedily, to have the operations of government go on speedily. Mr. Dooley says that a well regulated judge cannot think outside of a hammock and no one ever accused the judiciary of getting things done in a hurry. But the legislature from the very nature of legislative assemblies, cannot do that, either. The necessities of getting things done speedily as well as the necessities of individualization have made for a shift of the center of gravity in our institutions to the executive.

But one thing more—the conditions of modern business, the conditions of modern enterprise, the conditions of industry, require guidance during action. Well, now, the method of a legislature is to prescribe a path of action in advance. The judicial method is to scrutinize action after the event with reference to its conformity to certain established kinds. Neither the legislative nor the judiciary can furnish that individualized guidance that the economic organization of the country today demands.

Perhaps you could put it this way: I have always thought that the method of the legislature is the method that is employed when we draw a white line down the middle of the highway so a man can see whether or not he is in the prescribed path on his side of the road. The method of the judiciary is, after a man has gone across a crossing in a way he ought not to have done, and somebody has been injured, to tell him after the event how he ought to have done it, if he is alive to be told.

The administrative method is to have a man right there at the corner, signaling perhaps with both hands and his head in three different directions, stopping men here and urging them on there, and adapting the use of that crossing to the needs of the moment and the situation of traffic at the moment.

Now we can see why it is that all over the world, because that phenomenon is not confined to this country, there is a turn to the executive, where a generation ago in this country we looked to the judiciary, and before the Civil War we looked to the legislative.

The bearing of all this upon the question before us seems to me to lie in recognizing that very largely these problems, so far as effective remedies are concerned, have to do with effective administration and the question of how far that effective administration is legally possible under our polity, how far is it perhaps from an economic standpoint advisable, from a political standpoint wise.

It is legally possible, there cannot be any doubt, in view of the repeated tryings out of every phase of this matter which go on with every generation, not only in the United States, but in England, and, indeed, in every part of the English-speaking world.

Then, we come to the next matter, the matter of which Dean Bates spoke so admirably, the apportionment of power between state and nation. A great scholar in law and in politics, a continental scholar, has said that a prime characteristic of the races of northern Europe (and it is from those peoples, of course, that we took our political institutions) is what he called *kleinstadtismus*—smalltownism, but I would like to say Main Streetism. I say that with some assurance. I was born and brought up in a small town, a town through which Main Street ran in two directions—east and west, and north and south. I think I know something about Main Street because I was brought up at the corner of Main Street and Main Street.

That has been a fundamental mode of thought in our political and legal polity, a thinking in terms of the small economically self-sufficient local neighborhood. Of course, cooperation is something in which these neighborhoods were not interested. We have a beautiful example in New England, which is still very largely organized in a town system, in the town where I lived for a long time. I lived within about a quarter of a mile of the town line. Right over the line, in the adjoining town, was a fire station. In the town in which I lived, the fire station was a mile and a half down the road. When a barn burned within about fifty feet of the town line, but on my side of the line, the firemen in the adjoining town sat with their arms folded in easy chairs in front of the fire station and watched the proceedings while the fire apparatus came from a mile and a half down the road to put out the fire in their own town.

That is the kind of thing that has gone on from the beginning in our polity and it is significant for your purposes that it is that spirit, rather than anything that is in the Constitution, that we have got to get rid of. The Constitution does not in any wise fortify Main Streetism. But Main Streetism has furnished the picture that has been the background of application of more than one provision of the Constitution. And it is getting rid of that picture of the wholly self-sufficient community, the economically self-sufficient neighborhood, that really is at the root of the problems that you are dealing with.

That brings me then to the next matter, the matter of reasonableness. Under the Fifth and the Fourteenth Amendments and under provisions of state constitutions of like tenor in one way or another, things get down to a question of what is reasonable. The law is eternally telling us that things must be reasonable. But it does not tell us what is reasonable, and very largely it cannot. As Dean Bates admirably put it, we must deal there with a standard and not with a rule. What is reasonable under the circumstances in particular cases we have perforce to leave to the judges. We can put certain limits to the standard but within those limits what is reasonable has to be determined at the crisis of decision by the particular court that has the question before it. How does it decide what is reasonable? It does so, as I see it, with reference to certain established, certain received, certain authoritative ideals. What is an ideal?

I remember some years ago I was called on to deliver a commencement address at a university in one of the large cities of the land. It was hot weather and I was very much crowded. I did not have time to write the address, as I should have liked, but I chartered the stenographer at the hotel and began to dictate some notes to clarify my ideas, and among other things, I kept talking about idea and ideal. Presently the stenographer passed a handkerchief across a perspiring brow and looked up and said, "Dean Pound, gee, you do use highbrow words."

Let us not use that highbrow word "ideal." Ideal is from a Greek word that means picture, and picture gives us the notion exactly. Judges and lawyers have in their minds certain traditional, certain received, certain authoritative pictures of what they are doing and why they are doing it, pictures of what the legal order is for, pictures of what an American political society should be; and with reference to that picture, they determine what is reasonable.

So our trouble really is not with the Constitution, our trouble is with the picture that forms the background of application of the Constitution; and that picture in the past has been the picture of a society of economically independent, self-sufficient local neighborhoods, whereas

I undertake to say to you that we are one economically unified land; that the independent economically self-sufficient neighborhood is a thing not merely of the past, but of the long ago past; and, on the other hand, a picture of a society made up of economically self-sufficient individuals engaged in free competitive acquisition, each one carving out his own place for himself is a rural pioneer agricultural society.

The one picture is not any more true than the other. How many men in this great City of New York are engaged in free competitive acquisitive self-assertion, and how many are employees of great organizations engaged in cooperative enterprises? You have got to go a long way in this country to find the type of man who is pictured as the norm or the standard in that authoritative, in that received ideal which has been the background of application of the standard of reasonableness.

Of course, there we run into two words that have been very much abused, and I think we need to get rid of as soon as we can, two epithets—individualism and socialism. Those words do not mean anything any more. If we like a thing, we call it one, and if we do not like it, we call it the other. The most beautiful example of that, I think, was given some years ago in Henry Ford's explanation of what ailed the American farmer. I had supposed that the American farmer was the old guard of old-line American individualism. But Henry Ford explains that that idea is all wrong, that the trouble with the farmer, the reason why he is not getting anywhere in the American economic scheme, is that he is not an individualist. And as near as I can make out, the chain of reasoning is this, and it is very significant: Individualism is good, therefore what is good is individualism.

The methods whereby I have been able to make a billion dollars are good, therefore they are individualism. The methods of the American farmer will never make a billion dollars or any number of dollars for himself or anyone else, therefore they are not good. Therefore, they are not individualism. Q.E.D.

Of course, when words get to that point, it is time to give them up. It is not merely a matter of words. One of the vices, as I see it, of our thinking in the past has been that we have conceived that we have always got a choice of one thing or another thing, that there is no alternative, either this or that; we have got, irrevocably, for every purpose to go this way or inevitably and for every purpose to go that way.

I think we must learn, and it applies very immediately to your problems, that we are not driven to any choice of valuing everything in terms of individual, free, competitive self-assertion, individual, spontaneous initiative on the one hand, or on the other hand in terms of collective activity and community values. If there is any measure of value from an earthly standpoint, I suspect that it is civilization, the raising of human powers to their highest possible unfolding, that maximum of human control over external nature and over internal nature that has made it possible for man to inherit the earth and to increase and maintain that inheritance.

There, I think, is the picture, a picture that includes both individual, spontaneous initiative and cooperation and collective action and community of action. I suspect it is some such picture as that that is going to deliver the interpretation of the Constitution from the difficulties that Dean Bates pointed out so admirably, that is going to deliver you in the problems with which you are concerned from the difficulties that superficially stand in the way.

In everything that men do, let us remember we are governed by these pictures, by these ideals. I always like to think of Dickens' account of Mr. Podsnap in this connection. You remember Mr. Podsnap. He had done exceedingly well in the insurance business and he was very prosperous. His picture of life was getting up at eight, shaving at quarter past, breakfast at nine, going to the city at ten, returning at five, and dining at seven. Anything that fitted into that plan was right. If he had been a judge, it would have been reasonable. Anything that did not fit into that plan was wrong. Mr. Podsnap waved it behind him with a magnificent backward sweep of his arm and it perished from the earth. His answer to any difficult problem was very conclusive: "not English."

You see American judges in the last century telling us this thing or that was not compatible with the ideal of a free government, or was out of line with the axioms of free American institutions. That was a simply more beautiful way of putting Mr. Podsnap's proposition. They did not fit into the judicial picture of life.

I say to you, therefore, that it is these pictures that we must deal with; and the truth is, we have been dealing with them. The progress has been very considerable, a very great deal has gone on within a generation under the circumstances.

I am going to suggest to you just a few instances of what has gone on in a little more than a generation, certainly within fifty years, which certainly can give hope to anyone who is confronted with practical problems of the sort we are considering.

In the last century, one of the things upon which we laid stress particularly was freedom of contract. The courts told us that it was both a property right and involved liberty, that property involved free making of contracts and enforcement of them when they were made, and liberty involved the same thing. Well, think of the restriction of freedom of contract that has gone on in the last fifty years, for instance, standard policies of insurance. An insurance company cannot make any kind of a contract it wants. Standard policies are prescribed. It cannot make anything a warranty, for instance, that it wants to. Statutes and judicial decisions have taken away freedom of contract in that respect.

Or take the relation of employer and employee. The old matter of employer's liability is no longer a matter of contract; it is fixed by statute. Or, again, a corporation cannot, in many of our jurisdictions at least, pay its employees in orders on the company store. It has to pay wages in cash. I can go on—public service companies cannot make such contracts as they please. They can make such contracts as are pronounced by an administrative commission to be reasonable.

Or, again, the books in the nineteenth century told us that one of the necessary incidents of property, involved in the very ideal of property, was a free power of disposition of the property by the owner. Well, now that power of disposition has been limited in all sorts of ways. In a great many of our states if a man who owns property marries and he and his wife settle on the property as a family home, he cannot convey his own property without his wife joining in the conveyance. In one state, if a husband, by his own labor and the money he has earned, bought furniture, and he has it in his house and he marries, he cannot put a chattel mortgage on his own furniture acquired by his own exertions without his wife joining in that chattel mortgage. In another state, if a man has earned wages, if wages are something which he has earned with the sweat of his own brow, he cannot assign those wages unless his wife joins in the assigning, and so on. The books are full of cases where this power of disposing of one's property today is restricted.

But take something that touches you very immediately. Not so long ago we were told that the very idea of property involves a complete liberty of use and even abuse of that property. I was a student in law school in the year 1889, and I studied under a great property lawyer, who undoubtedly gave us very accurately the views that obtained at that time. It was his notion that if you and I had owned adjoining tracts of land, adjoining town lots, and you and I got into difficulty about something or other and I wanted to explain to you in a visible and tangible form what I thought of you, I could build a fence, if I kept it on my side of the line, nine feet high down that line and paint it all the colors of the rainbow and every kind of grotesque design on your side, and so long as I kept it on my side, you had nothing to say about it. Or I remember well he argued to us that if you had a well and you were downhill from me and the flow of water was in the direction toward your well, and for the mere pleasure of spiting you, I dug a well above yours so that the water did not come down to your well any longer, and I had no use for the water, but just ran it off and wasted it, that was my affair; I was operating on my land, and I had complete liberty to use or abuse that land as I chose.

Well, that doctrine is as dead as anything can be. A long time ago, relatively, as things are now, it was getting to be established; it is now established that a man has to make reasonable use of his land in those particulars and that something, which, without serving any beneficial interest of his, is an injury to his neighbor, and done with that in view, simply is not tolerated by the law today.

I remember when I came to the Bar, I had a case of this sort. Two neighbors had adjoining farms out on the prairie, and there ran down diagonally through these two farms what we called a "draw" on the prairie. Many of you are familiar with it—dry except when a heavy rain falls, then a great deal of water comes down. It came down in a sort of funnel, down to a creek, and the lower owner built a dam at the mouth of the draw, right where it went into the creek, and he built it carefully, of such a height that in case of rain, the water flowed back and made a pond for him to water his stock, but it did not flow back on his neighbor's land.

Well, he and his neighbor had a serious difference of opinion about the interpretation of the text of the book of Revelation, and that difference of opinion became so heated that the upper neighbor built a dam just inside the line across that same draw, so that water could not come down to the neighbor below any longer. As he had no use for the water, he dug a ditch that conveyed the water down into the creek.

That sort of thing was allowed by our courts in 1890, but I suppose it is not allowed anywhere to speak of today. We have come to feel that men have a liberty to make a beneficial use of their property, but that the use of this sort is anti-social; it does not make for civilization; it is not reasonable.

Another case that is very common today is restriction of the right of creditors to obtain a full satisfaction. A great French writer on these subjects said that by the nineteenth century law as it was in France a creditor could sell the property of his debtor, even to his shirt and trousers, to obtain the satisfaction of a judgment. But see what has been going on. There are not only homestead exemptions and exemptions of personalty, in England and some states of the United States there are provisions for judgments requiring payment in installments so that the debtor can make the payments with some regard for his maintenance, for his living and human life. There is a general tendency to hold that the creditor must take some part of the risk; that the risk is not entirely upon the debtor.

Another thing that touches very closely on what you are interested in. There has been a steady tendency to turn what we used to call *res communes* and things we called *res nullius*, into *res publici*. I suppose you all say, "Those are high-brow words." Here is what we mean: Certain things, it was said, were owned by no one, but they were subject to use by those who were in a position to use them, and certain other things, like wild game, were owned by no one but someone could take possession of them, reduce them to occupation and they became his.

Now more and more we have been getting provisions, in state constitutions, for instance, that these things, as it is said, are owned by the state in trust for the people. All that that very misleading phrase means is that there was a desire to make a legal basis for an administrative adjustment of the use of these things which would provide for the conservation of the natural resources of society and the maximum beneficial use of them consistent with that conservation.

Of course, in pioneer polity of our formative era, nobody cared anything about conservation. If a man did not find enough natural resources at his back door, all he had to do was to walk into the wilderness, and there they were. For a season, energy in appropriating, in utilizing these resources seemed to be the highest social and economic good. But these provisions I am speaking of, and many other things that I might bring to your attention, are in the direction of a continued, increasing recognition of a social interest in the conservation of social resources, a consciousness that that is reasonable also, quite as reasonable, and has to be reconciled with the free, spontaneous initiative to which alone we looked in the formative era.

There are other tendencies I might speak of, but I will speak of just one more. That is a tendency to give over the authoritative received picture of free competitive acquisitive activity as legally the highest good; a tendency to give over the common law version of monopoly, the common law idea that everything ought to be open to a free scramble of everybody, to recognize that there is waste and friction in that old picture appropriate to a rural pioneer agricultural society, but not appropriate to the economically unified land, the urban and industrial polity of today.

Perhaps I have said enough to show that the trouble very largely lies in these pictures and that the courts are conscious of it. I have given you examples and I could give you many more, but I want to make just one more point and that is that there has been an increasing tendency to look upon what is reasonable concretely rather than abstractly.

One of the great difficulties, as I see it, with our nineteenth century legal reasoning was that it was too much in the abstract. What was reasonable was what was abstractly reasonable. Reason is something that always has to be measured by the situation of the time and place, and you can see abundant example of a great change that is taking place in the judicial attitude in that respect. For example, after the Civil War, the Southern States were in a bad plight economically. A great part of their wealth was completely destroyed by the Thirteenth Amendment. Men who had been in affluence when they entered into contracts and assumed obligations when they had plenty of property, found themselves with no property and a great burden of indebtedness. So the Southern States adopted certain homestead exemption laws to relieve the pressure upon these debtors, to enable them to preserve something, to guarantee to them a minimum of human life. But, no, the Supreme Court of the United States said that would not do. In the Virginia homestead cases, the actual, the concrete situation was admirably presented, but the court would not look at anything but the abstract impairment of the abstract obligation, of abstract contracts. See the difference in the present century!

So far as I know, Dean Bates knows much better than I, the first case in which the court consciously looked at what was reasonable in the concrete was the decision on the Adamson law in 1916, when the court looked at the actual, the concrete, the de facto situation in American railway transportation at that time in determining what was reasonable. Then came the New York housing law and the District of Columbia rent cases, where again the court looked at the concrete situation in housing in our American cities after the war—in the most remarkable contrast to the homestead cases, of which I spoke a moment ago.

Then you are all familiar with the Minnesota moratorium case, in which the other day the Supreme Court of the United States again said, and indeed it read into the obligation of contracts, a power of the state to determine what was reasonable with respect to those contracts and that in an emergency things might be reasonable concretely, which in the abstract and in general would be unreasonable.

I confess I am a little afraid sometimes of that emergency proposition. I always think of a statute in my native state: "Be it enacted that the goldenrod, Solidago serotina, shall be the state flower of Nebraska, and, whereas, an emergency exists, this act shall take effect from and after its passage."

But perhaps it is reasonableness to have an emergency with respect to a state flower. The governor might have a ball the day after tomorrow, at which it would be advisable that the state flower be in evidence.

At any rate, that a concrete emergency may make things concretely reasonable is a perfectly reasonable proposition. So I think the suggestion I have to make to you is that when you are able to work out a program that is mechanically feasible, that is economically advisable, and which seems to your judgment, which is just as good as that of anyone, to be politically wise, you will not have very much trouble in the end in inducing the courts of today to find that it is legally sound.

Chancellor Kent was very much alarmed at the Louisiana Purchase. That great judge saw that ours was a polity made for small economically independent local neighborhoods. He saw the Louisiana Purchase was likely to be the beginning of a great unified state, reaching from ocean to ocean, and that was not the sort of thing that his fathers had built; it was not the sort of thing that existed at the time our constitutional polity was set up. He was very much afraid of it. He saw in it the wreck of our Constitution.

We say today that Chancellor Kent was wrong. He was wrong in one sense: he was right in another. That was the beginning of the end of Main Streetism. If we say we are in a revolution, we are in a revolution that began a long way back with the Louisiana Purchase and has gone right on to this day. But if it was the beginning of the end of small townism, it was not the beginning of the end, nor have we today come to the end of the Constitution—a great instrument of government, which through all economic changes, through all changes of the economic order and changes of social ideals, stands for the life measured by reason, stands for everything that makes for the reign of reason and of the will of God.

Modifying the Capture Law

By Earl Oliver,* Member A.I.M.E.

(New York Meeting, February, 1935)

Dean Roscoe Pound, of Harvard Law School, in addressing the A.I.M.E. Petroleum Division on Feb. 22, 1934, said, "When you are able to work out a program that is mechanically feasible, that is economically advisable, and which seems in your judgment, which is just as good as that of anyone, to be politically wise, you will not have very much trouble in the end in inducing the courts of today to find that it is legally sound."

The purpose of this paper is to show: first, legal conditions necessary to promote conservation and stabilization; and second, to suggest operating procedure when those legal conditions are established. The proposal is mechanically feasible and economically advisable. A growing public understanding should make it politically wise.

The disappointing progress in the development of conservation and stabilization can be attributed to the lack of two legal concepts as integral parts of oil and gas law; i.e., (1) a practical substitute for the capture rule, (2) collective ownership control for the individual oil and gas pool. When these two concepts are established on an equitable basis, conservation and stabilization procedure will become a comparatively simple process, more or less automatic in its adaptation and operation. Establishing these concepts is the function of the law-making agencies and might well be left to them for discussion except that the mechanical processes that give them form and substance must first be developed by the engineer.

A Substitute for the Capture Rule

Much has been written on these subjects, but the most concrete statement that has come to the attention of this writer is the following from an article by Charles G. Haglund in the *Kentucky Law Journal* of May, 1934:

> The Oxford[1] case is not only authority for the proposition that it is competent for the legislature to modify the old property law of capture with respect to oil and gas but that it may also delegate such authority to a subordinate body.

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[1] Oxford Oil Co. v. Atlantic Oil and Producing Co. 16F (2d) 639.

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> An estate at common law extends vertically upwards and downwards. Each landowner over the pool is equitably entitled to all the oil beneath his surface confined within those vertical planes as it exists in the pool in its original state and before any drainage has taken place. If that oil content can be determined * * * then all the surface owners over the pool can be treated as tenants in common of the contents of the pool in the proportion that the oil underneath his surface bears to the total contents of the pool. It will then be immaterial through which well the oil comes or on whose land the well is located. Each tenant in common of the pool will receive his proportional fraction of the oil that comes from the pool irrespective of where the wells are located. If that can be determined the pool can be developed as a unit along lines required to insure conservation and with justice to all the owners in the pool. That, however, presents an engineering problem which has not yet been fully solved * * * However, an approximate determination of the acreage content with adjustments as new knowledge is acquired by drilling would afford greater justice to all than the present system of competitive drilling where those with facilities for handling production generally get far more than their share. Then the amount of oil that the pool would produce by conserving the gas pressure would be much greater than under competitive drilling where it is wasted.

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> Certain legal principles which it is believed should be incorporated into the law of oil and gas have been worked out by lawyers and engineers, cooperating. The first principle clearly involves a determination of the acreage content before it can be administered. If this can be determined within reasonable bounds, not with mathematical accuracy, it should be sufficient. This determination, necessarily somewhat superficial at first, can be corrected and adjusted as development of the pool proceeds and new knowledge is acquired. Substantial justice to all is all that the law should require. Having achieved this, the law can declare the correlative rights of the various owners in the pool and make them tenants in common on the basis of such proportional determination of the contents of the pool. No constitutional objection to enforced unit operation on that basis can be perceived. All owners will then be required to share in the expense of development and in the proceeds from the pool in proportion to their fractional interest in the pool as tenants in common. A compulsory development program must include a provision whereby owners in the pool, collectively, shall set up their own machinery for development and determine, collectively, the policies to be pursued in the pool.

Dean Henry M. Bates, of Michigan Law School, expressed substantially the same idea in an address before the A.I.M.E. Petroleum Division on Feb. 22, 1934, during which he quoted for authority the Supreme Court of the United States in *Head v. Mgg.* Co., 113 U. S. 9 (See page 202, this volume).

W. P. Z. German, general counsel for the Skelly Oil Co., expressed the same idea in 1931 in the following words[2]:

> Many years ago it was stated by the courts that the Government has the power to prescribe regulations for the better and more economical management of property of persons whose properties adjoin, or which, for some other reasons, can be better managed or improved by some joint operation. This early announcement was quoted by the United States Supreme Court in *Wurts* v. *Hoagland*, 114 U.S. 606, 29 L. ed. 229. It was long ago held by courts, as is shown by quotations in the Wurts case,

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[2] *Trans.* A.I.M.E. (1931) **92,** 22.

> that where there are *adjoining lands held by various owners in severalty* and which, *by reason of the peculiar natural condition* of the whole tract, cannot be improved or enjoyed by any of them without the concurrence of all, there is presented a condition where the power of the legislature may be exerted to establish regulations whereby all may be compelled to submit to proceedings whereby they may be improved or enjoyed, and to contribute, in proportion to the benefits enjoyed by each, to the expense of the steps taken to accomplish such improvement or enjoyment.

He enlarged upon this idea at considerable length and shows that it has been widely applied for centuries in many lines of activity. He said:

> *This is a well-known legislative power recognized and treated by all the courts and writers upon law throughout the civilized world;* a branch of legislative power exercised both before and since the Revolution and before and since the adoption of the present Constitution.

Both Dean Bates and Mr. German show by an overwhelming array of citations and logic that the legal principles proposed by Mr. Haglund are in common application throughout the entire civilized world in many other lines of endeavor. The only reason that it has not also been applied to the oil industry in the United States arises out of the holdover impression from the pre-scientific days that oil and gas content cannot be determined with sufficient certainty to make that kind of a basis practicable.

Of course it will be acknowledged by every honest engineer that the apportionment cannot be made with mathematical accuracy, but few things in life can be done on that basis. It is after all a case of relativity—not as between mathematical accuracy and the nearness with which engineers can approach it, but rather as between the results under the capture rule and the results engineers can achieve under an attempted apportionment on the basis of relative recoverable acreage content. Given a virgin oil and gas reservoir, petroleum engineers could certainly devise methods of apportioning its contents that would measure up to the standard of reliability stated by Mr. Haglund. In fact, those who have made a study of reservoir conditions or engaged extensively in appraisal work know that can be done. Expressions by 17 nationally known American petroleum engineers on this point appear in the TRANSACTIONS[3].

It is obvious from the foregoing quotations that legalizing a practical substitute for the capture rule is entirely feasible. The exact detailed procedure by which it shall be made an integral part of oil and gas law is within the realm of the lawyer to plan. It will be an evolutionary process rather than the result of any one act. How much of it will result from court decisions, how much from state legislative enactments, and how much from some sort of Federal activity is dependent upon governmental policy. It is sufficient for the purpose of this paper to know that it can be accomplished within well established principles of law.

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[3] *Trans.* A.I.M.E. (1932) **98,** 31–37.

The capture rule has been aptly called legalized piracy. Its chief weakness is the inability of an owner to prosecute the man who damages him. Otherwise the owners of oil-producing lands would have been driven long ago to look for methods of oil extraction that would avoid that danger. If the owner of one piece of land in a common pool finds he cannot, under the method in use, take the oil out of his own land without danger of being prosecuted for also taking oil that belongs to his neighbor, he will be found willing to join in cooperative methods of extraction instead of capitalizing on the nuisance value of his individual holdings. Ability of an owner who is advantageously located to appropriate from the common pool more than the content of his land without being punished therefore is a major influence in preventing voluntary unitization of oil pools.

Collective Ownership Control

The second requisite above mentioned—collective ownership control for the individual oil and gas pool—has been referred to at length in the previous quotations. However, something further might well be said on this subject.

It is highly desirable that the new conception of oil production be so developed and applied as to retain to the owners of oil and gas properties the maximum degree of control over their own property consistent with protecting the public interest and securing the necessary concerted action. We believe that can be accomplished effectively if we study the manner in which society through past centuries has brought about concerted action in other lines of human endeavor. There are innumerable examples of this in which unity of action is attained without complete surrender of control of private property to governmental agencies to the extent that we daily observe in the oil industry under the existing proration systems.

Any rationalization program for the industry must comprehend many activities, some of which are peculiarly the function of Government and some peculiarly the function of the owners of the properties. It is highly desirable that these functions be kept distinct in our planning.

Determining the market demand, standards of waste prevention and correlative rights seems to be a function of Government, whereas the operation of oil and gas pools within those determinations of market demand, waste and correlative rights standards as found by Government would seem to be a function of the owners of the properties in question, either individually or collectively as the case might be.

Drainage districts, irrigation projects, and other lines of collective activity furnish both abundant legal precedent and examples of practical methods whereby the owners collectively manage their own projects through the assistance of machinery designed by the state. And there appears every reason why the owners in an oil and gas pool, or prospective pool, should be authorized by the state to organize that single pool into an oil and gas conservation district and bring about under their own guidance the concerted action that is so necessary to efficient exploitation of the pool. The precise organization form it should take is immaterial except that it should provide machinery for collective self-government in which owners are the authorized voters, and in which adequate safeguards are set up for the protection of minority interests involved.

Unitization Should Be Optional with Owners

The operating concept described by Mr. Haglund implies unit operation of the individual oil pool under a single collective management and with total disregard of property lines except in calculating allocation of the reservoir content between the respective owners. Unit operation enables most efficient use of reservoir energy and is the ideal method of operating an oil and gas pool. However, the two legal concepts first described can also be applied in the development of pools that are not unitized. They can be applied through well spacing and other planned development processes, but neither efficiency of extraction nor accuracy of allocation would approach the ideal that could be attained under unit operation. Mechanical processes rather than engineering calculation of relative acreage content would thus be used to determine apportionment among owners. Nevertheless, since each pool has individual characteristics, the owners collectively in each pool by some prescribed majority should be permitted to determine the general policies under which the pool is to be operated, assuming they remain within conservation and correlative rights standards that are compatible with public welfare.

Steps in Unitization

If the two foregoing concepts, namely, a practical substitute for the capture rule and collective ownership control for the individual oil and gas pools, become integral parts of oil and gas law, the steps involved in unitization become simple indeed. They are: (1) selection of areas to be unitized; (2) exploration procedure; (3) exploitation procedure.

The exact procedure that should be taken in each of these steps is impossible to forecast in the absence of legislation on which they would be based, but if the concepts stated become law, literally enforced, the resulting pressure will drive oil-field practice into proper channels, provided the change can be made so gradually as to give the industry time to adjust itself to the new concepts. Each successive step will appear clear as the problem unfolds. However, a few major principles that should dominate each step might well be considered here.

SELECTION OF AREAS TO BE UNITIZED

Oil pools already discovered and partly or fully drilled are like Humpty Dumpty of our nursery days. All the king's horses and all the king's men can't put them together again, nor does much reason exist why that should be attempted. The development was planned and costs were expended under the capture theory. Their energy and development losses have already occurred. They will gradually pass out of the picture through production decline and should be operated to exhaustion under the capture theory. With this exception the basic principles of ownership in place should supplant the capture rule at all points.

Legal justification for making a distinction between present producing pools and those yet to be discovered is to be found in the fact that development expenditures in present known pools have been made on the capture theory, and rights have become vested on that basis to a degree to which they have not become vested in undiscovered pools.

Assuming that the proposed change in oil and gas law relating to standard of participation has been established and that legal procedure to set up cooperative ownership control—as contrasted with individualistic development—has also been provided, every wildcat project undertaken will be planned on that theory and new pools as they are discovered will automatically come under it. The knowledge of each owner that he is entitled only to the recoverable content of his own land and is liable to prosecution if he appropriates his neighbor's oil or gas will drive him to a coöperative type of development under which each owner will receive his rightful share. This is unit operation in some form. The most effective type will gradually evolve out of the many forms that will be tried. Suitable steps in that process would be as follows:

Exploration Procedure

A lease owner, or lease owners, desiring to drill would apply to the authorized governmental agency for the establishment of an oil and gas conservation district according to the form that had been prescribed by statute. This district should be made large enough to include the single reservoir that might be discovered. The qualified voters of the conservation district (owners of property involved) would set up an executive management with such powers and duties as they deem wise to impose in it. That management would formulate an exploration program.

Finances for the initial expenditure would be supplied in the same manner that they are now supplied—by the owners of the bloc that promotes the test, with the difference, however, that they should be reimbursed out of the reservoir content if any is discovered. Where and how the potential oil pool would be tested and developed is a problem to be determined by the executive management appointed by the owners collectively. If oil or gas is found, a period of exploration, as contrasted with commercial exploitation, would ensue for the purpose of developing the necessary information on which to plan efficient extraction and determine apportionment between the respective owners on the basis of estimated recoverable acreage content. The character of data needed and the procedure for securing them have been described[4].

The interpretation of this information would be determined by some appropriate agency (for convenience called the allocation committee) organized by the owners collectively with the right of appeal therefrom by any aggrieved party. The exploration program would not only supply information on which percentage apportionments would be based, but by disclosing the limits of the pool it would automatically exclude from further participation in the management all whose lands lay outside these limits. It would also disclose reservoir conditions on which to plan most efficient extraction procedure. The cost of this exploration work should be made a lien upon the reservoir content, thus causing each owner to pay in proportion to the benefits received. If no reservoir is found, then, as under the capture rule, the cost would be a complete loss to those who financed the exploration project.

In many pools sufficient oil and gas can be extracted during the exploration period after the discovery well is drilled to completely pay for the exploration drilling expenses. No allocation of the production among the respective owners need be made until the exploration work is completed. In most cases all of it that is produced during that period would be consumed in paying for exploration development. The royalty oil could be held in a royalty fund for distribution at the end of the exploration period when the allocation determinations can be made.

Exploitation Procedure

When sufficient exploration information has been made available, the allocation committee would estimate the relative percentage of the reservoir content that is derived from each respective tract and make distribution on that basis, both to royalty owner and lease owner. The royalty oil would be delivered free of cost. The working-interest oil would be delivered subject to its pro rata share of the cost of extraction.

Of course there will be protests and suits over the allocations, but they will actually aid in the formulation of future unitization plans. The relative frequency of these disputes will depend upon the manner in which the allocation committee does its work. If it is handled so as to establish confidence in the fairness of the allocation committee, little trouble will arise; or at least it will not have much standing in court, for the court will require only a showing that best available methods are being honestly applied.

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[4] *Trans.* A.I.M.E. (1932) **98**, 31.

The reservoir content can be extracted through any well or wells best adapted to efficient utilization of the reservoir energy and then apportioned among the several owners in the proportion previously determined upon. Rates of extraction can be based on a schedule of crude requirements supplied by the several owners to meet their manufacturing and sales demands. Within a proper margin of safety one owner may have his oil delivered to him currently during one period while another may delay his delivery until a later period, according to their several desires. Gas may be delivered from oil wells down the slope to owners of free gas area on top of the structure, or it may be purchased and returned to the reservoir.

Delivery can be made in a multitude of ways that will harmonize more effectively with the individual needs of the several owners than present competitive methods of extraction allow. Titles to individual interests can be transferred more readily and with greater certainty of their actual value than under present methods. Oil can be sold to small refineries with greater freedom, and owners of small tracts can be more certain of getting their share of the oil than under present competitive methods.

The trouble that has developed through sale of royalty interests will disappear and all royalty interest purchasers will be certain to receive their share of the oil, regardless of whether a well is or is not drilled on the small tract in which they purchased a royalty interest. This does not occur under present competitive development methods.

If later development discloses that the original allocation schedule adopted at the end of the exploration period was not proper, later adjustments can be made as facts become disclosed.

PRACTICABILITY OF UNITIZATION PROGRAM

The foregoing program is based on the assumption that the two legal concepts described at the beginning of this paper can be installed as integral parts of oil and gas law. That change in the law cannot be secured until engineers convince legislative bodies and courts of law that the unitization procedure described herein is practicable and will benefit both the consuming public and the property owner. The most compelling proof would be examples of unitization projects that have been developed under the principles set forth.

Apart from securing changes in oil and gas law, there is one other method by which a virgin oil pool could be discovered, unitized and operated in the manner described. That is through voluntary agreement. However, experience has shown that ability to secure 100 per cent approval of both lease owners and royalty owners to a unitization project with its continuing relationships is so rare that general adoption of voluntary unitization under the capture rule is purely an idealistic theory. In every oil pool instances will occur where some one or more owners advantageously located believe they can secure more oil from the common pool by individualistic action than is contained within their own land. Human nature is too weak to sacrifice this personal advantage voluntarily for the common good and therefore voluntary unitization effort fails.

However, it should be possible to discover a few wildcat structures under sympathetic ownership that would be willing to have those structures utilized in the manner of laboratory experiments for the development of legal and engineering principles most suitable for the operation of oil pools under the new conception of oil field development. With evidence of the results obtained from these experiments, it should not be difficult to enlist legislative and judical coöperation in reshaping oil and gas law to harmonize with physical laws that control oil and gas deposits.

Conducting these laboratory experiments on virgin oil pools would fall logically within the province of the petroleum engineer. Sponsoring and guiding such experiments would be an unusually appropriate field of activity in which the A.I.M.E. Petroleum Division could render a distinct public service.

Chapter IV. Petroleum Economics

Domestic Consumption of Motor Fuel

By Albert J. McIntosh*

(New York Meeting, February, 1935)

One of the most interesting as well as important factors connected with the petroleum industry is the consumption of motor fuel. A few years ago we always spoke of "gasoline," but when natural gasoline and benzol became more important it seemed desirable to include all of these products in the petroleum statistics and so there was adopted the term "motor fuel," which embraces these three products in their entirety. Gasoline always included all stove and motor gasolines, high-grade naphthas, cleaning naphthas, solvents, varnishmakers' and painters' naphtha and gas-machine gasoline. "Motor fuel" includes all of these products also; therefore, technically the term "motor fuel" is incorrect, but as the total quantity of these non-motor naphthas is small their inclusion does not distort the results to any appreciable extent.

When the Federal Oil Conservation Board appointed its first semi-annual forecasting committee early in 1930 to project the demand for gasoline and crude oil into the year 1930, it was necessary for that committee to formulate a method of forecasting. It adopted the system in use by some of the oil companies at that time, of using automobiles and per-car consumption. Six months later the American Petroleum Institute also formed a committee for forecasting, which adopted the committee principle of asking each member to produce his own forecast of demand by any method he thought best and to give a full explanation to the committee. The result of the latter method was to get the benefit of as many different methods of forecasting demand as there were members. The writer does not recall any two members ever using exactly the same method. By studying the different forecasts and their methods, there evolved a composite opinion, which was presented to the industry as the committee's estimate. The same method has been followed by the American Petroleum Institute or Planning and Coordination Committee ever since.

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In all of these forecasts of demand, no matter what method was used, it became apparent that the forecasted trend of business was a controlling factor of very considerable importance. The early forecasts of the American Petroleum Institute Committee missed the mark every time because its members were not able to look into the future and foretell the extent of the business decline. The writer does not think the industry can blame them much for this, especially since the errors in those years averaged only about 3 per cent. The writer, in his own estimates for the Committee, was generally on the high side, because of his belief that business would soon snap back. However, it did not, and that was the primary cause of the smaller consumption of motor fuel.

It seemed to the writer that, if general business conditions were one of the controlling factors in forecasting, some method should be found to try and use these business indices to help in such forecasting. After some study the writer adopted a modification of the Harvard method, in use by the American Telephone and Telegraph Co. The general principles involved were the same as most mathematical methods of producing index numbers. Two things are generally done. First a seasonal variation is determined and then a long-time trend is calculated. Sometimes these seasonal variations appear to be the same year in and year out, while others appear to be subject to a gradual change. J. E. Pogue presented

TABLE 1.—*Demand for Motor Fuel in the United States*

FORECASTED "NORMAL" DEMAND FOR YEAR 1934

Month	Barrels	Month	Barrels	Month	Barrels
January	32,507,000	May	42,445,000	September	46,162,000
February	31,028,000	June	44,396,000	October	44,137,000
March	37,656,000	July	47,867,000	November	41,177,000
April	40,508,000	August	48,482,000	December	38,063,000

NORMAL FIGURES DIVIDED INTO ACTUAL[a] FIGURES AS PUBLISHED BY BUREAU OF MINES

Month	Per Cent	Month	Per Cent	Month	Per Cent
December, 1933	81.5	May, 1934	90.8	October, 1934	85.4
January, 1934	91.7	June, 1934	82.4	November, 1934	84.8
February, 1934	82.1	July, 1934	78.8	December, 1934	80.6
March, 1934	82.1	August, 1934	80.7	January, 1935	83.4[b]
April, 1934	81.5	September, 1934	76.1		

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[a] Writer uses A.P.I. basis; i.e., Bureau of Mines domestic demand plus loss in natural gasoline. This is the method adopted by the industry generally, but the Bureau of Mines has not adopted it.

[b] Estimated from Weekly A.P.I. figures.

this phase of the problem last year[1], and although his method is somewhat different from the method used by the writer, the results are very close. A changing seasonal calculation is clearly indicated and necessary for forecasting consumption of motor fuel. There is calculated then a set of monthly data representing what the "normal" figures should be, provided that the long-time trend continues at its usual rate and that the usual seasonal changes take place. The exact mathematics of this is somewhat involved but can be done by any comptometer operator after the formula is set down. This calculation for 1934 gave the results shown in Table 1.

Because these monthly index numbers vary considerably, the writer has adopted the method of smoothing them by using the average of three figures rather than just one. The reasons for extreme variations are many. To mention a few:

1. Exports reported in wrong month when compared to actual inventories reported.
2. Speculation on price changes causes abnormal shipments.
3. Errors in reports, which correct themselves in later months.
4. Taxes—Federal and State causing tax rushes or lags.
5. Abnormal seasonal changes.

By using a three months average—i.e., previous month, current month and following month—and plotting the result opposite the middle month, a much more smoothed trend is obtained. Of course, this always involves estimating one month ahead, but this can be done fairly closely by using weekly A.P.I. figures after a method adopted by statisticians who work on these problems. These are then corrected when the final results are obtained. These three months moving averages for 1934 were as follows:

	Per Cent		Per Cent		Per Cent
January	85.1	May	84.9	September	80.7
February	85.3	June	84.0	October	82.1
March	81.9	July	80.6	November	83.6
April	84.8	August	78.5	December	82.9P

Following this same method other years are calculated and plotted on a chart.

The purpose of all this, of course, is to see whether there is any relation between the changes in the trend of the consumption of motor fuel and business. There are any number of business indices available for use today. Some are weekly and others are monthly. The writer chose the business activity index as published by the *Annalist*. The charts used by the writer during the A.P.I. annual meeting at Houston, Texas, in November, 1933, carried only two lines, Motor Fuel Consumption and Business Activity. It became apparent from later study that gasoline had a good deal in common with other so-called consumptive goods indices. The writer, therefore, has adopted as an additional aid the index of "Distribution to Consumers" published by the Federal Reserve Board. This new line is shown on this chart. This Consumer index embraces department stores sales, chain store and mail order house sales, advertising and automotive sales. In order to follow the changes between the three lines, it is necessary to plot them on two different scales. A two to one relationship was used.

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[1] J. E. Pogue: Seasonal Variation in Gasoline Consumption. *Trans.* A.I.M.E. (1934) **107,** 142.

Some rather interesting things show up on the chart (Fig. 1). These same things, of course, are contained in the raw data but are more easily

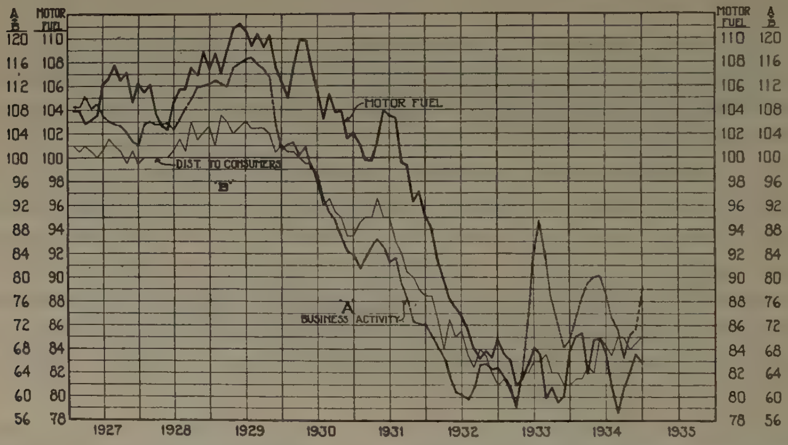

Fig. 1.—Indices of motor-fuel consumption in the United States, distribution to consumers (Federal Reserve Board) and business activity (*The Annalist*).
Gasoline index number corrected for seasonal variation and long-time trend (1921–32).

and clearly seen and understood through the use of this method of presentation.

Gasoline reached its peak in May, 1929. Some business indices also show this month as the high point of the business cycle, but the *Annalist* shows the high as July. Next can be seen the first effect of the depression. Gasoline started down in November and continued through January, 1930. The so-called Hoover bump in early 1930 is prominent in the motor-fuel index, which widened considerably during this period from the other two lines. This was due to the fact that the automobile was one of the last items to be curtailed by the average family. Later, when everyone realized that the country was facing a major depression and the good old days were over for a long time, they shut down on automobile use and the motor-fuel index not only followed the business indices downwards but lost all of its former advantage. The number of automobiles in use further substantiates this conclusion. See Table 2.

TABLE 2.—*Average Number of Automobiles in Use,* 1926 *to* 1934
(Expressed in Thousands)

Year	Old Cars Carried Over from Previous Year	New Cars Registered in Year	Total Cars Registered at End of Year[b]	Cars Not Registered Following Year	Cars in Use at End of Year	Average Cars in Use Full Year	Change from Previous Year, Per Cent
1926	18,273	3,864[a]	22,137	2,071	20,066	19,169	
1927	20,066	3,202[a]	23,268	2,369	20,899	20,482	6.8
1928	20,899	3,731[a]	24,630	2,384	22,246	21,572	5.3
1929	22,246	4,407	26,842[c]	3,059	23,783	23,015	6.7
1930	23,783	3,037	26,820	2,950	23,870	23,826	3.5
1931	23,870	2,222	26,092	2,980	23,112	23,491	1.4[e]
1932	23,112	1,277	24,389	1,976	22,413	22,762	3.1[e]
1933	22,413	1,739	24,152	1,344	22,808	22,611	0.7[e]
1934	22,808	2,292	25,100	2,000[d]	23,100[d]	22,954[d]	1.5[d]

[a] Adjusted by adding 250,000 each year to make up deficiency in figures reported.

[b] Includes federal and state nonregistered cars and dealers' cars (beginning 1929).

[c] Includes 189,000 dealers' cars—first time available, not used to calculate old cars carried over from previous year.

[d] Estimated.

[e] Decreases.

The average number of automobiles continued upwards through 1930 and did not start down until 1931. With the big drop in business plus the drop in automobiles in use in 1931 continuing lower into 1932, it was natural to expect the gasoline consumption to drop materially.

The writer was much interested in the rather close similarity between the business curve and that of domestic consumption of motor fuel. Most of the ups and downs in motor-fuel consumption find their explanation in the trend of business as indicated by the three lines charted. The similarity by years seems to be as follows:

1929—Peaks close and follows trend very closely.
1930—Hoover bump more pronounced for motor fuel—almost parallels business indices.
1931—Spring push up of business reflected in summer motor fuels. After this collapsed, no one knew where things would stop. Gasoline tobogganed.
1932—Business started up in July. Gasoline stopped its downward trend in September and paralleled business through to March, 1933.
1933—Gasoline improved only slightly as compared with business. This business improvement was largely in anticipation of N.R.A. codes and apparently did not benefit people by and large. After July when business slumped through to November, gasoline went down again even lower than before while business was held higher.

1934—Spring and early summer pick-up clearly reflected in gasoline. Summer and fall collapse also reflected with gasoline remaining just about as far below business as it was in November, 1933. Gasoline started up earlier than business and followed along, but is tending to lose some of the improvement noted in business.

It is shown very clearly that the motor-fuel index has gone practically sidewise since September, 1932. Both of the business indices used are trending upwards, however.

In order to forecast with this method, it is necessary to predetermine the trend of business, estimate the effect on gasoline, draw the forecasted line on the chart, read the index numbers and apply them against the calculated normal figures. The writer believes business will trend upwards for 1935; that motor fuel will lag in following business upwards and continue therefore its sidewise movements. This would give a forecasted domestic demand for 1935 of 425,000,000 bbl. or better.

The writer is also expecting that sometime within a year or two the gasoline demand will tend to close up the lag of the last two years. This may occur as early as the fall of 1935. This should not, however, be very marked.

The writer feels from his study of this situation that it is apparent that motor fuel has reestablished its old long-time trend, but at a lower level, and that the full effect of the depression on motor fuels has been to lose permanently about three years normal growth.

DISCUSSION

(*S. A. Swensrud presiding*)

V. R. GARFIAS,* New York, N. Y.—I do not want to appear facetious, but I am afraid my question may sound so. If you guess what is going to happen to gasoline from what you guess will happen to the business index, why not make one straight gasoline demand guess? In other words, you are basing a guess on another guess. It is all right for post-mortem studies to see how the thing happened, but if you are going to predicate your estimate of future gasoline consumption on a guess of business index, which in turn depends on so many factors, you are only complicating things.

A. J. McINTOSH.—I am rather lazy, and I do not always like to formulate every six months, at least it used to be every six months, some method of estimating motor fuel. I have adopted these mechanics; I just put down an idea, turn the crank, and out comes the answer. The reason I predicate on business is because I think business is the dog that wags the tail of motor fuel. I do not think motor fuel influences business, but I do think business influences motor fuel. It is in trying to understand how it influences it, and to better understand the data we get from the Bureau of Mines, that I play with it this way. I defy anybody to take the Bureau of Mines figures as they come out and get a true picture out of them, without correlating them somehow with business activity. It is in trying to correlate them that this method is worked out.

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* Henry L. Doherty and Co.

Collective Planning in the Petroleum Industry

By Joseph E. Pogue,* Member A.I.M.E.

(New York Meeting, February, 1935)

The petroleum industry has been involved in more collective planning than any other American industry, with the exception of the railroads and utilities, and therefore is of interest as a case study in the experimental attempts to regulate the economic consequences of free competition. Planning is of course an integral part of effective management, hence at the outset a distinction must be clearly drawn between competitive planning and collective planning. By competitive planning is meant the aggregate of plans drawn up and prosecuted by the competing units occupying a field of enterprise; by collective planning is meant a collusion of plans, either originating among some or all competitors, or else imposed upon them, whether accepted or resisted, by some superior authority, usually the state. The prevailing popular concept of "planning" as applied to industry appears to be a program of conduct superimposed upon an industry unwilling or incapable of achieving a socially and economically desirable result under free competition. In this brief and tentative analysis of the subject, competitive planning is left to one side and attention is focussed upon the matter of collective planning as defined above. A basic functional difference between the two categories of planning is that in the case of competitive planning the individual plans are small, numerous, and tend to offset one another when in error; whereas in the case of collective planning, the separate plans are larger in scope, fewer in number, and tend to escape the incidence of the principle of compensation.

In viewing the evolution of collective planning in the petroleum industry we find that during the past 20 years there have developed four more or less well defined collective plans and that at the present time the industry is deeply involved in a collective planning trend pointing toward further varieties. The four plans, which are to some degree transitional, may be conveniently named from the chief incidents that led to their formulations. The first collective plan was the program of control developed during the World War and hence called the *war plan*. The second plan was one originating within the industry in the period between the war and the inflation of the late twenties and called the *inventory*

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* Consulting Engineer, New York, N.Y.

plan because it involved the theory of stabilization by means of inventory accumulation. The third plan paralleled the rise of the late credit inflation and its resulting deflation and is termed the *proration plan* because it involved a regulation of crude oil supply through a pro rata distribution of existing demand to the various sources of supply. The fourth plan was inaugurated with the passage of the National Industrial Recovery Act and is called the *code plan* because it was developed under a system of industrial codification and operated under the Petroleum Code. These four collective plans will be examined in turn to see whether their specific application affords any basis for drawing economic deductions or generalizations bearing upon the practical application of collective planning in general.

THE WAR PLAN

The importance of the petroleum industry in the conduct of the World War led to the development of a program of emergency control upon the establishment of the Oil Division of the United States Fuel Administration on Jan. 10, 1918. Acting under the authority of the Food and Fuel Control Act of Aug. 10, 1917, the Oil Division was delegated with broad powers of regulation which were never called fully into action, owing to the successful development of a policy of cooperation between the oil industry and the Fuel Administration whereby the oil industry, acting through the National Petroleum War Service Committee, became a self-governing body cooperating with the objectives of the administration.[1] The Oil Division brought the oil industry into a plan to "stabilize prices and maintain uninterrupted flow of crude," which included voluntary agreements restricting prices for refined products. "The Plan," as the agreement came to be called, was approved in final form on Aug. 9, 1918, and operated until its dissolution on Dec. 12, 1918.

The objectives of the war control were to stimulate and coordinate supply, in the face of an augmented demand, and to prevent an undue rise in prices. There was no problem presented as to restricting supply, except in so far as some diversion of supply from less essential to more essential uses was brought about. The industry effectively cooperated to these ends; all essential requirements were met; and "the acceleration in crude prices was stopped, and a tempering effect exerted on the prices of petroleum products." The plan was an emergency measure and terminated at the close of the emergency. The features of the undertaking involved cooperative action under patriotic motivation, regulation of trade movements in the commodities involved, and a retardation of price advances.

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[1] See Pogue and Lubin: Prices of Petroleum and Its Products, 7–8, 26–29. War Industries Boards, Washington, 1919.

The Inventory Plan

The next collective plan to make its appearance in the petroleum industry was not formalized into an agreement, but arose from a prevailing state of mind that led to parallel action on the part of many units in the industry. This concert of policy can hardly be termed a collective plan in the strictest sense of the term, for cooperation and collusion may have been wanting from it and the element of competition between individual policies was present in it; yet, on the whole, the resulting action visible to the observer was tantamount to collective effort along a single line.

The entire concept here presented must be deduced from the recorded events that transpired and is not based upon documentary evidence. A study of the crude oil situation from about 1920 to 1927 reveals two striking features: (1) A succession of sharp up and down swings in the price of crude oil, a complete cycle being witnessed almost every year; and (2) a large accumulation of crude oil inventories. These circumstances, coupled with the fact that the industry had derived a crude oil scarcity complex from the war era of rising prices, indicate that there was a concert of plans to stabilize the industry by augmenting speculative purchases when prices were low. The motivating force was speculative on the theory that impending scarcity would create a profit; the mass effect, not perhaps appreciated at the time, was an inflation in demand that brought about higher average price levels than otherwise would have prevailed. The price levels thus created stimulated additional production so that not only did scarcity not eventuate, but on the contrary overproduction was sustained, and the accumulated results of this overproduction was retained by the industry in the form of a large inventory of crude, which is still on hand.

The Proration Plan

The third large plan that matured in the petroleum industry involved the activities combined under the term "proration." The proration plan did not spring into existence full grown but evolved from a small beginning and is still changing in structure. While initiated by collective action, this plan was not fundamentally of artificial origin but was the resultant of powerful economic forces engendered by the so-called rule of capture in oil-field development, when operating in the presence of excess capacity and violent changes in technology brought on by overcapitalization. Proration in an incipient state had made its appearance on previous occasions but in each case was abandoned upon the passing of the emergency that brought it into existence. Proration appeared again in 1927 to handle what was then believed to be a temporary period of overproduction in the Seminole area in Oklahoma. It was at first a voluntary effort localized in a single area, but as overproduction continued there and spread to other sectors, the proration function grew in scope and became institutionalized through enactment of legislation in several oil-producing states and through crystallization of trade practices.

The failure of the inventory plan made proration inevitable, once the momentum of supply carried unmistakably beyond consumptive requirements. The only alternative manner in which the economic forces could have relieved themselves would have been by direct impact with the rule of capture and through that encounter destroying it. Instead, the sequence of events followed an oblique course and modified the rule of capture by means of the institution of proration. It is manifest that the oil industry cannot function under an unmodified rule of capture, in the presence of production momentum in excess of market requirements. To debate, then, the desirability or otherwise of proration is to waste time upon an academic question: until nature reestablishes equilibrium, there are only two alternative procedures in the conduct of the petroleum industry; either the use of proration (in some form) as a production control or the destruction of the rule of capture. The former course has been elected by events and perhaps this avenue is one through which the rule of capture is to be slowly and laboriously done to death.

The proration plan has impressed far-reaching consequences upon the petroleum industry; some favorable, others harmful. On which side the balance lies is probably a problem in relativity; the subject is vastly complicated and in this place it must suffice merely to list the outstanding effects, as follows:

1. Proration sustained oil prices for a period but did not prevent an eventual decline in price levels.
2. Proration permitted the accumulation of a large hidden "inventory" in the form of the crude oil potential (i.e., drilled up but suppressed production).
3. Proration led to a major overdevelopment of marketing facilities as a terminal expression of the crude oil potential.
4. Proration led to a proliferation of state regulatory laws and brought the operation of the industry into the political arena. At the same time it led to advancement in the scope of state conservation laws.
5. Proration contributed to a change in the price concept, weakening the role of price as a mechanism for equalizing supply and demand, and furthering the idea of price as a reward of merit.
6. Proration built up a method of production control for balancing supply and demand in a volumetric sense, but in so doing stimulated disparity between the pressure aspects of supply and demand.
7. Proration caused a major advance in the technique of crude oil production by forcing many fields to be operated under conditions creating some to many of the efficiencies of unit operation[2].

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[2] Unit operation, it should be noted, involves the complete negation of the rule of capture.

The proration plan involves a system of quotas limiting crude oil production to estimated demand. Within the states the estimated demand is allocated to the separate fields and to the individual leases comprising the fields through the agency of state regulatory bodies or cooperative committees; and enforcement is based upon state laws prohibiting waste. The determination of state quotas, always a difficult problem, was first systematically attacked by the Federal Oil Conservation Board in 1930, when it appointed a Committee on Petroleum Economics to prepare advisory state allocations—a function that has been carried over into the petroleum code. The idea of a possible need for a more formal coordination of the several states has given rise to periodic attempts to develop an Interstate Oil Compact, which would bring the oil-producing states and the Federal Government into a joint plan of production control.

The proration plan, contrary to the war plan and the inventory plan, has not been superseded but was utilized and elaborated under the ensuing program of the code plan.

THE CODE PLAN

The code plan originated in the social and economic stress of the depression and therefore was superimposed upon the industry, which willingly lent its cooperation because the new instrumentality of control was developed in the midst of one of the periodic breakdowns in the functioning of proration. Thus the code plan bears more structural resemblance to the war plan than to the two intermediate plans: the war plan and code plan were initiated by forces outside the confines of the oil industry proper and each involved cooperation between the Federal Government and the industry, with the principle of industrial self-government brought to the fore; the inventory plan and proration plan were internal in origin and only one of them transgressed the industrial boundary, and that only to the extent of involving the police power of the oil-producing states. All efforts to create a new variant, by engaging the Federal Government and the states in the joint enterprise, have thus far failed, wrecked on the shoals of states' rights, although such efforts have lately been renewed under the leadership of the Governor-elect of Oklahoma.

The Petroleum Code rests upon the authority of the National Industrial Recovery Act and the objectives of the code may be stated to have been: (1) to improve the buying power and working conditions of labor; (2) to balance supply and demand; (3) to restrict importations of oil; (4) to conserve the resource; and (5) to "stabilize" oil prices. The code carried price-fixing sections, which were never invoked in a formal manner, although the operation of the code contributed to a pegging of crude oil prices at a dollar level, to an advance in discounts allowed gasoline resellers, and to numerous attempts to bring gasoline prices at wholesale and retail into a parity zone relative to the dollar base for crude oil.

It is perhaps too early to arrive at impartial judgment as to the initial results of the code plan, but as in the case of the proration plan the consequences have been far-reaching, some advantageous and others harmful. The subject is very involved and the attempt can only be made here to list, with scant discussion, the principal effects of sixteen months' operation under the code:

1. The code plan through control of production maintained approximate volumetric equilibrium between supply and demand, but was aided in this objective by the instrumentality of proration which the plan embraced but did not originate. The code plan was less successful in regulating the *pressures* of supply and demand, so that a balanced price structure was not achieved.
2. The code plan restricted the volume of imported oil, but did not coordinate the program in respect to the different commodities affected and the international aspects of such action.
3. The code plan passed over the fundamental cause of disequilibrium in the petroleum industry, the rule of capture, and concentrated its conservation efforts upon the development of plans for the drilling of new oil fields.
4. The code plan sought to freeze crude oil inventories, thus tending to prevent the liquidation of the economic error committed during the operation of the inventory plan.
5. The code plan devoted much time and effort to the creation of artificial price conditions through price-fixing of one sort or another.
6. The code plan contributed to the expansion of an already overdeveloped marketing situation by stimulating increases in reseller margins[3].
7. The code plan created a far-flung and complex organization for the direction and enforcement of the plan; and led to a centralization of authority in two bodies representative of the Federal Government and of the industry.

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[3] The marketing situation, which has attracted such a plethora of discussion, is fundamentally simple; merely permit retail prices to be wholly governed by wholesale prices, with a narrow spread between, and everything possible will have been done to recreate economic balance in this department of the business. But this price relationship is exactly what both the code plan and the industry prior to the code have striven sedulously to avoid—perhaps with some reason, so far as the code plan is concerned, for oil marketing is a social problem as well as an economic one. The oil industry has been severely criticized for the waste involved in the extensive duplication in its gasoline distributing facilities and efforts. From the point of view of social reform, however, it would seem that far from being censored on this score, the industry should be commended for creating such an effective mechanism for the redistribution of wealth!

8. The code plan developed a Federal Tender System which proved for a period to be an effective instrumentality in regulating the shipments of "hot" oil from the East Texas field.
9. The code plan applied the system of centrally coordinated production quotas developed by the late Federal Oil Conservation Board and sought to extend a similar procedure to the field of refining.
10. The code plan enlarged the share of labor in the gross income of the industry and increased the bargaining strength of labor in respect to rates of pay and conditions of work.
11. The code plan emphasized the national aspects of the petroleum industry and sought to establish the authority of the Federal Government to regulate the movement of oil across state boundaries when in excess of state production quotas.
12. The code plan assisted the industry to make modest profits but was aided in this result by underlying improvement in the industry arising from natural causes.
13. The code plan brought all elements in the industry into closer contact with problems of collective management and contributed an important stimulus toward the better understanding of these issues.

CHARACTERISTICS OF COLLECTIVE PLANNING

The data provided by four examples are obviously a meager basis for deductions of general application. Nevertheless the field of observation is one of the best available and at least the indicated tendencies may be noted as characteristic phenomena, without implication as to their continuity or extension. Whether undertaken by the industry as a whole or by governmental authority, or by the two in combination, the nature and functioning of collective planning seem to run rather consistently along parallel lines. The outstanding features of collective planning as exemplified in the petroleum industry appear as follows:

1. Collective plans are developed in periods of economic stress to prevent the extension of undesired tendencies.
2. The motives for collective planning are expected profit—financial, political, or social.
3. The avowed purposes of collective planning are price stabilization, prevention of waste, and redistribution of advantage.
4. The methods used in furthering collective plans are cooperation, legal coercion, and centralization of authority.
5. The sponsors of collective planning are the industry, the state, or the two in conjunction.
6. Collective planning tends to be diverted from fundamental considerations and to address itself to opportunistic measures. To

win popular support, collective planning is forced to work toward the attainment of primary economic resultants, overlooking the secondary and tertiary consequences which are often the reverse of the objectives sought.

7. Collective planning centers its efforts upon price regulation, seeking to direct price movements along lines favorable to preconceived objectives. This aim is supported by measures designed to alter the forces of supply and demand, but overt price-fixing efforts are employed as a major instrumentality. The sharp focus on price results in the creation of counter economic pressures that call forth additional measures for their control.
8. Collective planning leads toward progressive complexity in administration and increasing centralization of authority.
9. Collective planning is a powerful instrumentality of change and its application should be the subject of critical study in order to eliminate such of its imperfections as may be purely functional.

Trend of Collective Planning in the Petroleum Industry

This brief review is perhaps sufficient to indicate that collective planning in the oil industry has developed by a series of stages and presents an evolutionary aspect. The industry is now operating under a collective plan, or more properly under a combination of two collective plans, with progressive changes in structure still under way. While the drift is toward still further complication in structure, the end point in the process of change cannot be clearly perceived. The alternative destinations, however, may be blocked out in rough outline, as follows:

1. A fully centralized plan, under federal authority, tending to restrict competition, regulate volume and prices, and limit growth and change.
2. A decentralized plan combining proration with relative freedom of prices and preservation of competition.
3. A reversion to competitive planning.

Proven Reserves of Mineral Fuels in the United States

By Valentin R. Garfias,* Member A.I.M.E.

(New York Meeting, February, 1935)

A survey of the resources of mineral fuels, coal, petroleum and natural gas presupposes a clear distinction between the known amount underground and the "proven reserves"; the portion that can be economically brought to the surface and made available for utilization.

Only a fraction of the coal and petroleum in producing fields is or can be economically brought to the surface and not all of this is economically utilized; also, although practically all the natural gas can be economically recovered and utilized, in actual practice a large part of the total volume that reaches the mouth of the wells is wantonly blown into the air and wasted. It is thus estimated that of the total amount of coal underground about 40 per cent remains unrecovered, or is otherwise wasted, before it reaches the consumer; that only some 25 per cent of the petroleum in proven fields is actually brought to the surface; and that even if practically the entire volume of natural gas can be economically utilized, in actual practice close to 25 per cent of the total produced is now absolutely wasted. And the dissipation of this gas, unwarranted as it is, not only diminishes the gas supply but diminishes also the proven reserves of petroleum from such fields as the Panhandle of Texas, where petroleum and natural gas are produced simultaneously.

Many factors affect the estimates of the proven reserves of mineral fuels, such as the capacity and nature of the reservoir, its depth, the quality of the product, the efficiency of recovery, the price of the fuel and its byproducts, etc., etc., but superseding at times all of these in connection with petroleum and natural gas deposits is the effect of "subsoil ownership" on the rate and methods of exploitation of the deposits. As a result it should be a comparatively simple matter to eliminate waste and overproduction, and thereby increase the proven reserves of petroleum and natural gas, in Russia, Iran and Iraq, where the subsoil rights are nationalized, or in any country in which there is or can be quickly established an effective legal control of the underground deposits and the manner of their exploitation. It has been and it is now, on the other hand, almost an impossible undertaking to intelligently regulate the petroleum and natural gas production in the United

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States, where the ownership of these products is based on the paramount right of the individual surface owner to "capture" within the boundaries of his property all the oil or gas under his land or migrating through it. This unlimited "right to capture" results, among other things, in the blowing daily into the air of over 1,000,000,000 cu. ft. of natural gas in the Panhandle field alone, a very high price for the State of Texas and the United States to pay for the sake of perpetuating these antiquated and destructive laws, which place the individual above national rights and affect national security through the wanton and irreparable destruction of these essential munitions of war.

Table 1 shows that the proven coal reserves of the United States are equivalent to some 4800 years supply at the present rate of production, that reserves of natural gas theoretically can take care of present demand for some 20 years, and proven petroleum reserves represent close to 14 years supply on the basis of present consumption. Obviously the present rate of production of these fuels cannot be maintained until the entire supply is exhausted, therefore any shortage will be experienced before that time, if consumption is to be met by present proven reserves. Approximate as these figures are, nevertheless they clearly show: (1) that the United States is amply supplied with coal for future needs, (2) that natural gas is available for consumption for the comparatively short time of some 20 years, (3) that the proven petroleum reserves are inadequately small, more so than those of natural gas, (4) that the "law of capture" is the paramount handicap affecting economic oil and gas recovery, and to it can be chiefly ascribed the appalling waste of natural gas and the uneconomic recovery of petroleum and natural gas and (5) that no permanent remedy of these conditions can be expected until the "law of capture" is superseded or basically modified to make possible the economic development and exploitation of oil and gas fields through the "unit plan" of operation or some other similar effective method.

TABLE 1.—*Proven Reserves of Mineral Fuels in the United States*

	Coal, Million Net Tons	Natural Gas, Trillion Cu. Ft.	Petroleum, Bbl.
1934 production	390	1.633[b]	910,051,000
Total production to end of 1934	21,300[a]	30.310[c]	16,600,419,000
Proven reserves at end of 1934	3,414,550	40.000[d]	13,000,000,000

[a] Does not include about 9 billion tons of coal left in the mines, or otherwise wasted. [b] Does not include some ½ trillion cu. ft. blown into the air and wasted in 1934. [c] Does not include some 8 trillion cu. ft. blown into the air and wasted from beginning to date. [d] Includes some 10 trillion cu. ft. that will be wasted if production methods continue as at present and if the "law of capture" is not superseded or intelligently modified.

World's Consumption of Petroleum Products

By V. R. Garfias* and R. V. Whetsel,* Members A.I.M.E.

(New York Meeting, February, 1935)

For some time the writers have been compiling and analyzing statistics of consumption and production of petroleum, its products and related fuels, in order to arrive at a fairly accurate picture of the world-wide situation of the petroleum industry. In production, crude oil, natural gasoline, benzol and alcohol blended with motor fuel have been considered. In consumption not only refined products, but crude consumed as fuel, refinery losses, ships' bunkers and blended fuels have been taken into account to obtain a true balance between supply and demand. Statistics from practically every country and territory have been studied, and where actual figures were not available the estimates have been based on all the data available.

The figures in Table 1 indicate that during the last five years the world's production has exceeded demand every year and that the aggregate difference is some 207,150,000 bbl. The supply in the United States exceeded consumption by 111,401,000 bbl. over the same five-year period and in 1931 and 1932 the demand exceeded supply, while outside the United States the excess of output over demand was 95,749,000 bbl. Table 2 combines the excess production in the United States with its favorable balance of exports over imports, showing that the United States has reduced its storage over the five years by about 136,595,000 bbl., while in Table 3 it is shown that, including its excess of imports from the United States, the rest of the world has added 343,745,000 bbl. to storage during the period in question, the greatest accumulation coming in 1934. Table 4 shows the world's consumption classified by countries according to the principal products.

These tables also indicate that at the end of 1934 the statistical position of the petroleum industry outside the United States was decidedly unstable, a situation that probably will become more acute as a result of the added Iraq production; and that the present favorable statistical position of the industry in the United States, which is partly due to the excess of exports over imports, may be to some extent jeopardized by the unstable situation in the foreign market.

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TABLE 1.—*Production and Consumption of Oil*

THOUSANDS OF BARRELS

Year	World Production	World Consumption	Excess Production over Consumption
1930	1,477,989	1,428,499	49,490
1931	1,432,142	1,417,374	14,768
1932	1,362,039	1,348,407	13,632
1933	1,467,128	1,406,923	60,205
1934[a]	1,553,100	1,484,045	69,055
	7,292,398	7,085,248	207,150

[a] Estimated from statistics available in December.

TABLE 2.—*Amount of Oil to Storage, United States*

THOUSANDS OF BARRELS

Year	Excess Production over Consumption	Excess Imports over Exports	Total to Storage
1930	30,700	R 51,939	R 21,239
1931	R 5,815	R 38,788	R 44,603
1932	R 13,011	R 28,781	R 41,792
1933	67,427	R 60,254	7,173
1934[a]	32,100	R 68,234	R 36,134
	111,401	R 247,996	R 136,595

[a] Estimated from statistics available in December.

TABLE 3.—*Amount of Oil to Storage, World Outside United States*

THOUSANDS OF BARRELS

Year	Excess Production over Consumption	Excess Imports from U.S.A. over Exports to U.S.A.	Total to Storage
1930	18,790	51,939	70,729
1931	20,583	38,788	59,371
1932	26,643	28,781	55,424
1933	R 7,222	60,254	53,032
1934[a]	36,955	68,234	105,189
	95,749	247,996	343,745

[a] Estimated from statistics available in December.

TABLE 4.—*World Consumption of Petroleum Products and Related Fuels*

THOUSANDS OF BARRELS

	1932						1933		
	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total	Motor Fuel	Kerosene	Gas and Fuel Oil
United States	377,791	33,221	308,157	16,614	99,699	835,482	381,561	38,440	321,395
Russia	7,607	23,464	58,492	5,292	4,260	99,115	8,838	24,722	51,818
United Kingdom	30,328	5,283	19,280	2,462	1,810	59,163	33,220	5,480	21,900
France	19,571	1,584	8,828	1,768	1,814	33,565	21,268	1,522	12,594
Canada	14,435	1,558	13,153	746	2,060	31,952	15,016	1,608	13,520
Germany	12,789	960	3,996	2,015	1,620	21,380	12,373	841	6,429
Argentina	4,835	832	12,244	287	820	19,018	5,301	1,064	12,678
Japan	5,234	850	6,227	982	530	13,823	5,650	1,006	7,781
Mexico	1,724	567	9,820	109	2,413	14,633	1,765	583	11,091
Rumania	706	1,225	9,701	190	2,020	13,842	726	1,262	10,076
British India	2,389	6,916	3,668	770	1,036	14,779	2,085	5,899	3,382
Italy	2,915	1,102	5,323	801	229	10,370	3,001	1,133	7,296
Dutch East Indies	1,687	2,510	5,750	531	1,356	11,834	1,500	2,275	4,610
Australia	5,359	990	772	313	513	7,947	5,724	1,201	2,631
Dutch West Indies	156	19	5,200	22	2,820	8,217	160	21	5,100
China	675	3,674	1,530	194	85	6,158	744	4,460	2,184
Iran	461	1,200	3,200	670	1,230	6,761	673	1,285	3,259
Holland	2,891	1,346	1,376	352	202	6,167	3,291	1,464	1,992
Venezuela	474	25	4,866	42	350	5,757	507	17	4,922
Brazil	1,790	590	2,312	149	20	4,861	2,005	629	2,945
Sweden	2,921	612	1,602	321	60	5,516	2,930	719	2,003
Spain	3,122	165	1,728	210	280	5,505	3,032	215	1,502
Belgium	2,266	720	984	590	103	4,663	2,589	304	978
Denmark	1,980	639	1,605	181	14	4,419	1,840	680	1,630
Egypt	413	2,142	1,231	114	102	4,002	419	2,061	1,506
Cuba	699	173	2,784	52	40	3,748	504	114	2,840
Union of South Africa	1,901	415	404	130	147	2,997	2,149	451	560
Norway	847	277	1,335	69	48	2,576	895	264	2,090
Phillipine Islands	759	560	1,824	74	102	3,319	891	590	1,790
Czechoslovakia	2,001	220	337	190	32	2,780	1,911	353	712
Switzerland	1,736	194	862	150	25	2,967	1,661	186	1,014
Hawaiian Islands	905	106	1,449	45	72	2,577	909	129	1,624
New Zealand	1,669	159	968	62	41	2,899	1,590	120	780
Poland	643	944	328	357	452	2,724	780	943	401
Trinidad	110	61	2,690	31	236	3,128	122	63	2,030
British Malay	508	230	2,308	62	110	3,218	414	259	1,519
Chile	410	64	1,415	32	18	1,939	520	63	1,358
Uruguay	581	180	1,363	23	7	2,154	590	210	1,410
Panama Canal Zone	78	22	1,631	8	7	1,746	80	24	1,792
Iraq	141	153	530	33	156	1,013	185	182	832
Irish Free State	1,110	420	103	65	124	1,822	1,101	416	110
Austria	840	243	425	127	12	1,647	848	276	643
Algeria	930	364	187	81	70	1,632	1,138	377	244
Peru	342	328	590	31	165	1,456	428	461	509
Hungary	435	495	207	41	20	1,198	431	489	341
Greece	402	166	722	67	32	1,389	393	147	777
Puerto Rico	391	59	943	23	16	1,432	449	65	806
Portugal	392	315	266	34	38	1,045	432	368	267
Finland	442	344	76	63	50	975	511	282	96
French Morocco	726	125	83	38	91	1,063	696	100	77
Others	5,092	4,211	14,530	891	710	25,435	5,142	4,367	15,114
	528,609	103,022	529,405	38,504	128,267	1,327,807	540,988	110,190	554,958

TABLE 4.—(*Continued*)

	1933 (*Continued*)			1934[a]					
	Lubricants	Miscellaneous	Total	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total
United States	17,066	108,068	866,530	406,000	43,700	329,000	18,600	115,700	913,000
Russia	6,121	4,001	95,500	9,840	25,280	52,500	6,800	4,400	98,820
United Kingdom	2,937	2,430	65,967	34,500	6,260	25,700	3,020	3,170	72,650
France	2,019	1,156	38,559	21,400	1,810	12,720	2,100	1,360	39,390
Canada	757	1,912	32,813	16,200	1,700	14,200	800	1,600	34,500
Germany	2,001	1,893	23,537	14,200	860	7,500	2,200	1,700	26,460
Argentina	283	910	20,236	5,480	1,200	12,900	260	970	20,810
Japan	1,478	470	16,385	6,000	1,200	9,600	1,500	400	18,700
Mexico	121	2,175	15,735	1,880	600	11,280	140	2,400	16,300
Rumania	195	1,625	13,884	770	1,250	11,400	200	2,000	15,620
British India	877	920	13,163	2,150	6,000	3,500	950	930	13,530
Italy	642	240	12,312	3,240	1,200	7,800	640	250	13,130
Dutch East Indies	544	1,171	10,100	1,520	2,330	5,000	550	1,300	10,700
Australia	336	388	10,280	5,820	1,250	2,900	330	400	10,700
Dutch West Indies	24	2,795	8,100	170	30	5,700	30	3,100	9,030
China	264	93	7,745	900	3,900	2,500	250	100	7,650
Iran	660	1,410	7,287	700	1,200	3,300	700	1,600	7,500
Holland	427	137	7,311	3,280	1,460	1,770	390	330	7,230
Venezuela	28	380	5,854	590	20	5,200	30	500	6,340
Brazil	165	17	5,761	2,280	700	3,100	190	20	6,290
Sweden	294	116	6,062	3,090	725	1,920	310	135	6,180
Spain	174	360	5,283	3,290	200	1,630	190	350	5,660
Belgium	242	107	4,220	3,000	350	990	320	140	4,800
Denmark	182	8	4,340	2,160	630	1,580	195	15	4,580
Egypt	165	69	4,220	430	2,100	1,600	170	80	4,380
Cuba	41	38	3,537	490	120	3,000	40	30	3,680
Union of South Africa	154	147	3,461	2,200	460	700	160	150	3,670
Norway	92	60	3,401	980	270	2,060	90	50	3,450
Phillipine Islands	102	90	3,463	860	580	1,800	70	80	3,390
Czechoslovakia	214	30	3,220	1,960	280	800	200	35	3,275
Switzerland	137	12	3,010	1,780	200	1,100	140	20	3,240
Hawaiian Islands	44	59	2,765	920	130	1,800	50	60	2,960
New Zealand	72	71	2,633	1,680	110	950	70	80	2,890
Poland	308	378	2,810	750	920	380	310	360	2,720
Trinidad	30	210	2,455	120	70	2,200	30	280	2,700
British Malay	52	216	2,460	450	260	1,500	50	220	2,480
Chile	43	10	1,994	560	60	1,780	40	10	2,450
Uruguay	29	11	2,250	660	230	1,500	30	10	2,430
Panama Canal Zone	8	17	1,921	90	30	1,900	10	20	2,050
Iraq	39	210	1,448	310	200	1,200	60	240	2,010
Irish Free State	61	150	1,838	1,180	420	160	70	150	1,980
Austria	137	16	1,920	830	270	650	140	20	1,910
Algeria	107	86	1,952	1,000	370	350	100	80	1,900
Peru	32	190	1,620	440	480	520	40	230	1,710
Hungary	58	89	1,408	500	490	480	70	100	1,640
Greece	41	30	1,388	390	150	900	40	30	1,510
Puerto Rico	22	20	1,362	460	70	850	20	30	1,430
Portugal	31	40	1,138	460	380	260	30	40	1,170
Finland	65	58	1,012	530	290	80	70	60	1,030
French Morocco	48	60	981	710	110	90	50	60	1,020
Others	984	985	26,592	5,300	4,500	15,600	1,000	1,000	27,400
	40,953	136,134	1,383,223	574,500	117,405	577,900	43,845	146,395	1,460,045

[a] Estimated from statistics available in December.

Chapter V. Production

Introduction

By Frank A. Herald,* Member, A.I.M.E.

In order to facilitate interpretation of the data in this chapter, we print the following excerpts from my circulars to authors:

> Generally in Table 1 the unit for presentation of data is a field. For our purposes a field is defined as the whole of a surface area wherein productive locations are continuous. Such unit commonly includes and surrounds nonproductive areas. Such unit commonly includes a great variety of geologic conditions—several units of continuous productive reservoirs of distinctly different structure and of distinctly different stratigraphy. Therefore it is hoped that our authors will subdivide "field" so as to enable students to make analyses that may have scientific and/or commercial value.
>
> As to each space in the tabulation, it is either (1) not applicable, (2) the proper entry is not determinable, (3) the proper entry is determinable, but not determinable from data available to the author, (4) the proper entry is determinable by the author. In spaces not applicable, the author will please draw horizontal lines; in spaces where the proper entries are not determinable, the author will please insert x; in spaces where the proper entries are determinable but not determinable from data available to the author, the author will please insert y; in spaces where the proper entries are determinable by the author he will, of course, make such entries. Generally, y implies a hope that in some future year a definite figure will be available.
>
> Inability to determine precisely the correct entry for a particular space should not lead the author to insert merely y. Contributions of great value may be made by the author in many cases where entries are not subject to precise determination. In such cases the author should use his good judgment and make the best entry possible under the circumstances. For many spaces, the correct entries represent the opinion of the author (for example, "Area Proved") and in such cases the entries need not be hedged to such extent as in cases where the quantities are definite yet can be ascertained only approximately by the author.
>
> In cases under definite headings but where figures are only approximate, the author may use x. For example, if the total production of a field is known to be between 1,800,000 and 1,850,000, the author may report 1,8*xx*,*xxx*; or if the production is between 1,850,000 and 1,900,000, the author may report 1,9*xx*,*xxx*.
>
> Where a numeral is immediately to the left of x or y, such numeral represents the nearest known number in that position.
>
> As to quantity of gas produced from many fields the question will arise as to whether the figures should include merely the gas marketed or should include also estimates of gas used in operations and gas wasted. Although rough approximations may be involved, our figures should represent as nearly as possible the total quantity of gas removed from the reservoir.
>
> While we have not provided a column for showing the thickness of the productive zone, generally the difference between average depth to bottoms of productive wells

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* Consulting Petroleum Geologist and Engineer, Fort Worth, Texas; Vice Chairman for Production, A. I. M. E. Petroleum Division, 1933 and 1934.

and average depth to top of productive zone will represent approximately the average thickness of the productive zone. For fields where this is not true because of unusually high dips, or for other reasons, it is suggested that the authors indicate in their texts the approximate average thickness of the productive zone.

The figure representing net thickness of producing rock should correspond to the total of the net portions of the producing zone which actually yield oil into the drill hole. It is recognized that for some fields the authors can make only rough guesses—so rough that figures would be of no value. In such cases the authors should enter either *x* or *y*, whichever is more appropriate. Production per acre-foot will have to be treated, of course, in the same manner for the corresponding fields.

We are particularly anxious to have every author give due consideration to the determination of structural conditions of each oil and/or gas body. Please consider each oil and/or gas reservoir and indicate its structure. The mere fact that a reservoir is on an anticline is not proof that the structural condition affecting the accumulation is anticlinal; for example, an oil and/or gas body limited by the upper margin of a lens on the limb of an anticline is "ML" as to structure. By all means, if the oil body occupies any position in the lens other than its upper limit, please so indicate clearly by footnote, for "ML" means, unless modified, that the accumulation is at the upper part of the lens. In every case where the oil and/or gas body terminates short of the up-dip continuity of the reservoir, please carefully check your evidence and then appropriately record your conclusion. "Terrace," "Nose" and "Syncline" are the only terms in our legend which presume such continuity.

Please note that the heading "Number of Dry and/or Near-dry Holes" is intended to cover only such holes as are within the limits of the defined fields. The holes entered here will be distributed in Table 2 by counties and by depths.

FOOTNOTES TO COLUMN HEADINGS—TABLE 1

[a] In areas where both oil and gas are produced, unless gas is marketed outside the field, such areas are included in column headed "Oil." Manufacture of casinghead gasoline and carbon black is interpreted as outside marketing of gas.

[b] Production per acre is determined by dividing into the number of barrels of oil the sum of the number of acres assigned to "Oil" plus such number of acres of the total assigned to "Oil and gas" as represents the portion thereof occupied by oil.

[c] Wells producing both oil and gas are classified as "Producing oil only" unless gas from them is marketed off the lease.

[d] W, water; G, gas; A, air; AG, air-gas mixture. Numbers following letters indicate number of injection wells.

[e] Bottom-hole pressures are preceded by "e." All other figures represent pressures at casinghead with well closed.

[f] P, paraffin; A, asphalt; M, mixed.

[g] Cam, Cambrian; Ord, Ordovician; Sil, Silurian; Dev, Devonian; Mis, Mississippian; MisL, Lower Mississippian; MisU, Upper Mississippian; Pen, Pennsylvanian; Per, Permian; Tri, Triassic; Jur, Jurassic; CreL, Lower Cretaceous; CreU, Upper Cretaceous; Eoc, Eocene; Olig, Oligocene; Mio, Miocene; Pli, Pliocene.

[h] S, sandstone; SH, sandstone, shaly; Ss, soft sand; H, shale; L, limestone; LS, limestone, sandy; C, chalk; A, anhydrite; D, dolomite; Da, arkosic dolomite; GW, granite wash; P, serpentine.

[i] Figures are entered only for fields where the reservoir rock is of pore type. Figures represent ratio of pore space to total volume of net reservoir rock expressed in per cent. "Por" indicates that the reservoir rock is of pore type but said ratio is not known by the author. "Cav" indicates that the reservoir rock is of cavernous type; "Fis," fissure type.

[j] A, anticline; AF, anticline with faulting as important feature; Af, anticline with faulting as minor feature; AM, accumulation due to both anticlinal and monoclinal structure; H, strata are horizontal or near horizontal; MF, monocline-fault; MU, monocline-unconformity; ML, monocline-lens; MC, monocline with accumulation due to change in character of stratum; MI, monocline with accumulation against igneous barrier; MUP, monocline with accumulation due to sealing at outcrop by asphalt; D, dome; Ds, salt dome; T, terrace; TF, terrace with faulting as important feature; N, nose; S, syncline

[k] Information will be found in text as indicated by symbols; A, name of author, other than above, who has compiled the data on the particular field; C, chemical treatment of wells; G, gas-oil ratios; P, proration; U, unit operation; R, references; W, water; O, other information.

Oil and Gas Development in Arkansas in 1934

By H. K. Shearer,* Member A.I.M.E.

(New York Meeting, February, 1935)

Drilling for oil and gas in Arkansas in 1934 showed more activity than in any year since 1929; with a total of 96 completions, including 36 oil wells, 1 gas well and 59 dry holes. Of the producers, the lone gas well and 35 oil wells were in old fields, and one wildcat producer opened a new pool. Of the dry holes, 16 were in or near fields and 43 were wildcats. The total reported initial daily production of the oil wells was 9013 bbl., averaging 252 bbl. per well. Active drilling operations numbered 65 at the close of the year, compared with 26 at the beginning.

Table 1.—*Oil and Gas Production in Arkansas*

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres			
			Oil	Oil and Gas[a,3]	Gas	Total
	Oil Fields (Southern Arkansas)					
1	El Dorado, *Union*	15	8,000	x	x[3]	8,000
2	Irma, *Nevada*	14	820	x	x[3]	820
3	East El Dorado[1], *Union*	13	1,420	x	x[3]	1,420
4	Stephens, *Columbia, Ouachita, Nevada*	13	3,000	x	x[3]	3,000
5	Smackover, *Ouachita, Union*	13	25,600	x	x[3]	25,600
6	Heavy oil area	13	16,000	x	x[3]	16,000
7	Light oil area	13	9,600	x	x[3]	9,600
8	Bradley, *Lafayette*	10	80	0	0	80
9	Lisbon, *Union*	9	2,700	x	x[3]	2,700
10	Champagnolle[2], *Union*	8	2,000[4]	x	x[3]	2,000
11	Mt. Holly, *Ouachita*	6	60	0	0	60
12	Urbana, *Union*	5	400	x	x[3]	400
13	Garland City, *Miller*	3	300	0	0	300
14	Camden, *Ouachita*	0	x	0	0	x
15	Total, oil fields		44,380	x	x[3]	44,380
	Gas Fields (Northern Arkansas)					
16	Mansfield, *Scott, Sebastian*	33	0	0	3,000	3,000
17	Massard Prairie, *Sebastian*	31	0	0	3,000	3,000
18	Kibler, *Crawford*	20	0	0	3,100	3,100
19	Williams, *Crawford*	17	0	0	4,000	4,000
20	Clarksville, *Johnson*	14	0	0	2,650	2,650
21	Alma, *Crawford*	13	0	0	1,640	1,640
22	Lavaca, *Sebastian*	5	0	0	3,000	3,000
23	Shibley, *Crawford*	5	0	0	2,560	2,560
24	Total, gas fields		0	0	22,860	22,860
25	Total, Arkansas		44,380	x	22,860[3]	67,240

[a] Footnotes to column headings and explanation of symbols are on page 249.

[1] Including Woodley pool in secs. 5, 6, 7 and 8, T. 18S., R. 14W.; also sec. 14, T. 18S., R. 14W. and sec. 2, T. 18S., R. 15W.

[2] Sometimes called Rainbow City.

[3] El Dorado, Irma, East El Dorado, Smackover, Lisbon and Champagnolle produced large quantities of gas from tops of structures or upper edges of sands in earlier years. The gas was largely wasted, but some was used commercially. Stephens produced some gas from Nacatoch and Urbana from 2,700-ft. sand.

[4] Tokio sand covers 300 acres; Crain, 900; Gregory, 800; Taylor, 400; partly overlapping.

Manuscript received at the office of the Institute Feb. 18, 1935.

* Geologist, The Hunter Company, Inc., Shreveport, La.

Oil production in Arkansas has declined every year since the Smackover peak in 1925; but the total of 11,416,440 bbl. in 1934 showed a decline from the preceding year of only 47,225 bbl., or 0.4 per cent. Production was held up by working over and more continuous pumping of old wells in all fields, as well as by the completion of a number of good producers in the Champagnolle, Urbana and Garland City fields. There was an increase in production from the Irma and Stephens fields also.

Production per producing well in Arkansas from discovery to the end of 1934 has been: El Dorado, 40,200 bbl.; Irma, 37,340; East El Dorado, 46,880; Stephens, 17,700; Smackover, 92,450; Bradley, 37,320; Lisbon, 17,180; Champagnolle, 55,160; Mt. Holly, 19,510; Urbana, 83,080; Garland City, 30,550; average for state, 70,540.

Camden.—The only new field discovered during the year was opened by the T. J. Gaughan et al. No. 1 Bragg, SE. of NW. of SE., sec. 25-13S.-18W., 4 miles west of Camden. This well made a good showing of heavy oil on drill-stem test early in December, and was completed Dec. 26, pumping about 100 bbl. per day from the Nacatoch sand at 1356 to 1369 ft. Probably it opens a small fault-line field of the same type as Irma. Already there were four dry holes within a 2-mile radius and at least 20 within 5 miles. A south offset well had tested water in the producing sand before the end of the year.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells		
	To End of 1934	During 1933	During 1934	Daily Average during Dec., 1934	Per Acre to End of 1934[5]	Per Acre-foot to End of 1934[5]	Per Well Daily during Dec. 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	During 1934	
													Completed	Abandoned
1	44,705,060	775,895	712,320	1,830	5,558	280	7.5	x[3]	0	0	0	1,112	0	0
2	5,303,240	231,000	300,780	933	6,470	431	14	x[3]	0	0	0	142	0	0
3	8,440,120	177,720	171,730	475	5,940	594	7.5	x[3]	0	0	0	180	0	6
4	5,328,295	144,305	227,020	605	1,776	254	3	x[3]	0	0	0	301	3	10
5	344,105,855	8,892,655	8,051,230	21,230	13,440		11	x[3]	0	0	0	3,722	3	26
6	293,956,295	7,944,915	7,174,915	18,930	18,372	460	14	x[3]	0	0	0	y	y	y
7	50,149,560	947,740	876,315	2,300	5,217	175	4	x[3]	0	0	0	y	y	y
8	186,705	0	0	0	2,333	466	0	0	0	0	0	5	0	0
9	6,118,695	150,345	136,070	355	2,266	113	2	x[3]	0	0	0	356	0	16
10	10,756,810	497,225	523,965	3,565	5,380	359	56	x[3]	0	0	0	195	6	7
11	117,085	0	0	0	1,950	280	0	0	0	0	0	6	0	0
12	2,158,880	484,810	848,755	2,275	5,400	540	99	x[3]	0	0	0	32	10	0
13	549,870	105,210	444,660	1,320	1,840	184	94	0	0	0	0	18	13	0
14	500		500					0		0		1	1	0
15	427,771,025	11,459,165	11,416,940	32,558	9,639		11.6	x[3]	0	0	0	6,070	36	65
16	0	0	0	0	0	0	0					9	0	
17	0	0	0	0	0	0	0					90	0	
18	0	0	0	0	0	0	0					40	0	
19	0	0	0	0	0	0	0					45	0	
20	0	0	0	0	0	0	0	12,930	2,322	2,420	15	12	0	0
21	0	0	0	0	0	0	0					33	0	
22	0	0	0	0	0	0	0					16	0	
23	0	0	0	0	0	0	0					6	0	
24	0	0	0	0	0	0	0					251	0	
25	427,771,025	11,459,165	11,416,940	32,558								6,321	37	

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[5] Acre-foot figures are of little significance in these fields, because of number of sands and doubtful net thickness.

Champagnolle.—The Short and Hayes No. 1 Taylor, NW. of NW. of SE., sec. 10-17S.-14W., in the center of the Gregory sand producing area of the Champagnolle or Rainbow City field, discovered a new and deeper producing sand when it was completed Nov. 11, flowing 866 bbl. per day, from a sand at 3361 to 3366 ft. This has been named the "Taylor" sand, and is 60 or 70 ft. below the lower "Gregory" sand. By the end of the year five more wells had been completed in this sand or another lens, all between 3300 and 3362 ft. deep. There were also five dry holes completed, which practically limit the producing area of the new sand to about 400 acres, entirely under the older Gregory sand producing area. At Champagnolle, as in most of the other south Arkansas fields, production is localized by depositional conditions rather than structure, oil and gas being found in the upper edges of sand beds which either pinch out or grade into tighter formations. Therefore, any well drilled in or around this field may find good production at almost any depth.

Other Fields.—Until November, when the Champagnolle drilling activity started, most of the drilling was in the Urbana and Garland City fields. The producing areas of these fields are not yet entirely defined,

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells				Average Depth, Ft.		Oil Production Methods at End of 1934		Pressure, Lb. per Sq. In.[6]			Character of Oil Approx. Average during 1934				
	At End of 1934						Number of Wells		Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulfur, Per Cent	Base/
	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping		1933	1934	Maximum	Minimum	Weighted Average		
1	15	242	0	242	2,177	2,100–2,550–2,950	0	242	*x*	0	0	39	30	32	1.0	M
2	0	69	0	69	1,179	1,150	0	69	*x*	0	0	16	14	15	2.7	A
3	5	64	0	64	2,180	2,170	0	64	*x*	0	0	21	17	19	1.8	A
4	8	191	0	191	2,110	1,500–2,100	0	191	*x*	0	0	33	13	28	2.9–1.6	A, M
5	98	1,959	0	1,959			0	1,959	960–1,100	0	0					
6	83	1,341	0	1,341	2,025–2,475–2,610	2,000–2,450–2,600	0	1,341	*x*	0	0	25	17	20	2.2	A
7	15	618	0	618	2,025–2,300	2,000–2,275	0	618	*x*	0	0	32	25	26	1.8	M
8	0	0	0	0	2,790	2,785	0	0	*x*	0	0	28	25	27	*y*	M
9	2	176	0	176	2,120	2,100	0	176	*x*	0	0	38	28	33	1.0	M
10	7	64	0	64	2,800–3,030–3,215–3,350	2,780–3,000–3,200–3,340	5	59	1,120	0	*y*[6]	37	18	29	1.1	M
11	0	0	0	0	2,813	2,800	0	0	*x*	0	0	32	28	30	*y*	M
12	3	23	0	23	3,560	2,700–3,550	0	23	*x*	0	0	20	16	17	2.1	A
13	4	14	0	14	2,935	2,925	0	14	*x*	0	0	33	27	31	1.2	M
14	0	1	0	1	1,369	1,356	0	1	0		0			17		A
15	142	2,803	0	2,803			5	2,798								
16		0			1,553	1,125–2,010			315	140						
17		0			1,724	1,296–2,180			220–265	25						
18		0			2,054	1,310–2,175			220–260	40						
19		0			2,387	1,510–2,375			220–265	60						
20	0	0	9	9	2,838	1,061–2,275–3,066			345–690–1,275	100–950						
21		0			2,538	1,668–2,600			330–420	75						
22		0			2,972	2,900			270	260						
23		0			1,271	1,150			200	130						
24		0														
25		2,803					5	2,798								

[6] New flowing wells in Taylor sand have some pressure.

although no large extensions are probable. The Stephens field was extended northwest into Nevada County by a small producer.

A second deep test for the Smackover field is to be started early in 1935. This well will be drilled by the Gulf Refining Co. in the Louann area, in sec. 5-16S.-16W., evidently with the intention of testing the west flank of the salt mass discovered by the previous deep test in sec. 4-16S.-15W.

Wildcats.—Miller, Lafayette and Union counties had most wildcat drilling, with respectively nine, eight and six completions of tests far enough from production to be called wildcats. A reported show of oil in a well in sec. 5-19S.-28W., Miller County, near Bloomburg, Texas, led to the drilling of several other dry holes in the southwestern corner of Arkansas.

The deepest test of the year was the Erwin et al. No. 2 Bodcaw Lumber Co., in sec. 19-16S.-23W., near Stamps, Lafayette County. Drilled to test a fault structure believed to be similar to the Rodessa gas field in Louisiana, this well passed through the Glen Rose anhydrite at 3400 to 3631 ft. and was abandoned at a total depth of 5032 ft., still in the lower Trinity red beds.

Although not spectacular, the results of development of the Champagnolle, Garland City and Urbana fields have been profitable enough to

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1934		Producing Rock					Structure[j]	Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	B.t.u. per Cu. Ft.	Gals. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.			Name	Depth of Hole, Ft.
1			Nacatoch[7]	CreU	S	Por	20	ANL	157	Trinity	3,396
2			Nacatoch	CreU	S	Por	15	AF	25	Trinity	3,735
3			Nacatoch[8]	CreU	S	Por	10	TL	39	Trinity	3,765
4			Nacatoch, Buckrange	CreU	S	Por	15–7	NLf	44	Trinity	4,502
5									359		
6			Nacatoch, Graves, Tokio	CreU	S	Por	40	As	x	Pre Cre (?) salt	7,255
7			Nacatoch, Meakin	CreU	S	Por	30	TLf	x	Trinity	y
8			Buckrange	CreU	S	Por	5	T?	4	Trinity	3,555
9			Nacatoch	CreU	S	Por	20	ML	18	Trinity	3,509
10			Tokio, Trinity[9]	CreU, CreL	S	Por	15	NL	119	Trinity	4,533
11			Trinity	CreL	S	Por	7	ML	14	Trinity	3,378
12			Trinity	CreL	S	Por	10	A?	31	Trinity	4,501
13			Trinity[10]	CreL	S	Por	10	ML	25	Trinity	4,519
14			Nacatoch	CreU	S	Por	12	F?	1	Trinity	2,500
15									836		
16	893	0	Atoka	Pen	S	Por	210	D	9	Atoka	2,635
17	892	0	Atoka	Pen	S	Por	150	A	1	Atoka	3,175
18	895	0	Atoka	Pen	S	Por	66	A	2	Atoka	3,002
19	893	0	Atoka	Pen	S	Por	66	A	16	Atoka	2,754
20	895	0	Atoka	Pen	S	Por	28	A	5	Atoka?	5,597
21	893	0	Atoka	Pen	S	Por	30	A	8	Atoka	3,077
22	893	0	Atoka	Pen	S	Por	10	A	0	Atoka	3,235
23	893	0	Atoka	Pen	S	Por	y	A	2	Atoka	2,380
24									43		
25									879		

[7] Also small production from Meakin and Tokio sands.

[8] One well producing from the Tokio at 2,865.

[9] W. C. Spooner includes Crain and Gregory sands in upper Cretaceous Tokio-Woodbine division, although they have generally been called Trinity.

[10] Producing sand may be basal Woodbine.

TABLE 2.—*Summary of Drilling Operations in Arkansas*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to January 1, 1935								Completed during 1934								Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes							Productive Wells	Dry and/or Near-dry Holes									
	Total Depths, Ft.						Total	(For Details, See Table 1)	Total Depths, Ft.						Total	Productive Wells (For Details, See Table 1)	Within Fields	Exploratory
	500–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000			500–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000				
Arkansas	2	5	4	2	0	0	13	0	0	0	0	0	0	0	0	0	0	1
Ashley	0	0	4	14	0	0	18	0	0	0	0	1	0	0	1	0	0	1
Benton	1	4	2	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Boone	1	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Bradley	5	2	4	15	1	0	27	0	0	0	0	1	0	0	1	0	0	0
Calhoun	0	3	12	17	1	0	33	0	0	0	0	2	0	0	2	0	0	1
Carroll	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Chicot	1	0	3	5	0	0	9	0	0	0	0	0	0	0	0	0	0	0
Clark	6	11	4	2	0	0	23	0	0	0	0	0	0	0	0	0	0	0
Clay	1	6	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Cleburne	0	1	0	2	1	0	4	0	0	0	0	0	0	0	0	0	0	0
Cleveland	2	4	3	6	0	0	15	0	0	0	0	0	0	0	0	0	0	0
Columbia	3	9	45	31	1	0	89	202	0	0	0	3	0	0	3	0	0	0
Conway	0	2	2	3	0	0	7	0	0	0	0	1	0	0	1	0	0	0
Craighead	0	5	2	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Crawford	0	1	39	5	0	0	45	124	0	0	0	0	0	0	0	0	0	0
Crittenden	1	1	3	2	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Cross	1	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Dallas	1	6	10	3	0	0	20	0	0	0	0	0	0	0	0	0	0	0
Desha	1	1	0	3	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Drew	2	8	9	8	0	0	27	0	0	0	0	0	0	0	0	0	0	0
Faulkner	0	1	1	3	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Franklin	1	5	7	1	0	0	14	6[2]	0	0	0	0	0	0	0	1	0	0
Garland	2	2	0	1	1	0	6	0	0	0	0	0	0	0	0	0	0	0
Grant	1	7	14	1	0	0	23	0	0	0	0	0	0	0	0	0	0	0
Greene	0	2	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Hempstead	9	7	22	2	0	0	40	0	0	0	0	2	0	0	2	0	0	2
Hot Spring	0	10	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Howard	4	10	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0
Independence	0	3	2	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Jackson	4	2	1	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Jefferson	8	5	7	2	0	0	22	0	0	0	0	1	0	0	1	0	0	0
Johnson	1	1	4	6	0	0	12	12	0	0	0	0	0	0	0	0	0	0
Lafayette	4	12	38	19	0	1	74	5	0	1	1	5	0	1	8	0	1	3
Lee	1	0	1	1	0	0	3	0	0	0	0	1	0	0	1	0	0	0
Lincoln	0	1	5	0	2	0	8	0	0	0	0	0	0	0	0	0	0	0
Little River	9	9	12	3	0	0	33	0	0	0	0	0	0	0	0	0	0	2
Logan	1	5	6	2	3	0	17	1[2]	0	0	0	0	0	0	0	0	0	0
Lonoke	1	1	7	0	0	0	9	0	1	0	0	0	0	0	1	0	0	1
Madison	0	2	2	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Miller	2	20	37	30	4	0	93	19[1]	0	0	6	6	1	0	13	13	8	7
Mississippi	1	4	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Monroe	1	1	1	1	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Montgomery	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Nevada	5	42	25	7	2	0	81	143	0	0	0	0	0	0	0	1	1	1
Ouachita	1	35	127	24	1	0	188	1413	0	3	2	1	0	0	6	5	1	2
Perry	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Phillips	4	4	1	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0
Pike	3	4	3	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Poinsett	1	1	5	3	0	0	10	0	0	0	0	0	0	0	0	0	0	0

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[1] Includes one short-lived producer outside of Garland City field, not counted in Table 1.

[2] Not listed in Table 1.

encourage wildcatting for similar small fields in the Tokio-Woodbine and Trinity red beds formations, and others probably will be opened from time to time. Discoveries will be needed to prevent a continued decline in production, because during 1934 oil prices were high enough to keep all the older fields operating at the limit of their productive capacity.

ACKNOWLEDGMENTS

The writer wishes to acknowledge information and assistance received from the geological and scouting departments of the various companies operating in Arkansas, particularly those of the Standard Oil Co. of Louisiana and the Arkansas Louisiana Gas Co. Much of the material in the tables was carried on from the similar review for 1933 by Prof. B. C. Craft[1]. Revisions of Table 1 as to productive acreage, sand depths, nomenclature, etc. have been made largely on the basis of the recently published paper on Oil and Gas Geology of the Gulf Coastal Plain in Arkansas by W. C. Spooner[2], a report that makes generally available for the first time much information regarding the oil fields of Arkansas.

TABLE 2.—(*Continued*)

County	Completed Prior to January 1, 1935									Completed during 1934								Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes								Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes							Productive Wells (For Details, See Table 1)		
	Total Depths, Ft.							Total		Total Depths, Ft.						Total		Within Fields	Exploratory
	500–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	7000–8000			500–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000				
Polk	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Pope	0	7	3	4	3	0	0	17	3^2	0	0	0	0	0	0	0	0	0	0
Prairie	2	1	6	1	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Pulaski	4	4	1	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0
Randolph	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
St. Francis	1	0	5	3	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0
Saline	1	0	2	3	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0
Scott	0	7	7	0	0	0	0	14	3	0	0	0	0	0	0	0	0	0	0
Searcy	0	2	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Sebastian	4	6	13	3	1	0	0	27	112	0	0	0	0	0	0	0	0	0	0
Sevier	4	2	2	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0
Union	10	29	320	209	8	0	1	577^3	4289	0	1	6	9	1	0	17	17	24	9
Van Buren	0	2	1	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Washington	2	7	2	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0
White	1	5	2	2	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Woodruff	1	4	3	0	0	0	0	8	0	0	0	2	0	0	0	2	0	0	0
Yell	1	5	6	2	0	1	0	15	0	0	0	0	0	0	0	0	0	0	0
Total	125	348	855	452	29	2	1	1812	6332	1	5	17	33	2	1	59	37^4	35	30

[3] Incomplete. [4] Oil 36, gas 1.

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[1] Trans. A.I.M.E. (1934) **107,** 177.

[2] Written for the Arkansas Geological Survey and privately printed by Parke-Harper Printing Co., Little Rock, Ark., 1935.

Developments in the California Oil Industry during the Year 1934

By V. H. Wilhelm,* Member A.I.M.E.

(New York Meeting, February, 1935)

Greater stabilization in the petroleum industry was effected during 1934 through stricter compliance with curtailment measures and the establishment of the Pacific Coast Petroleum Agency. Various estimates of individual, company and state reserves revealed the fact that they were inadequate to sustain the present rate of production over a lengthy period, therefore drilling operations were increased during the year both in proved and wildcat territory.

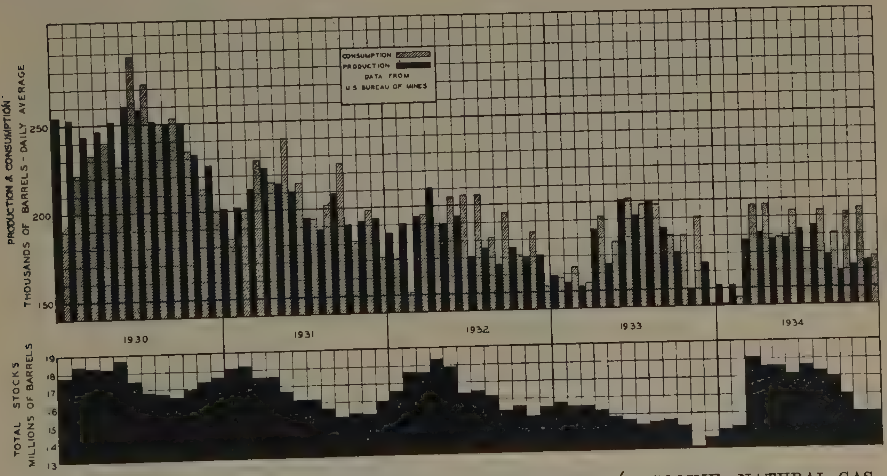

Fig. 1.—Production and consumption of motor fuel (gasoline, natural gasoline and engine distillate) for California.

This greater activity resulted in the addition to reserves at Mountain View, Mount Poso and Edison in Kern County, Santa Barbara in Santa Barbara County and Playa del Rey in Los Angeles County. Additional reserves were also established in the Long Beach and Santa Fe Springs fields, in Los Angeles County, due to operators being successful in isolating small prolific sand bodies, formerly disregarded during the flush production periods.

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However results as a whole increased accessible reserves at the expense of total reserves. Since 1928, withdrawals have been 500,000,000 bbl. greater than additions. At the present time withdrawals from accessible reserves are at the rate of 1 per cent a month from settled fields and as high as 2 per cent a month from flush fields. Withdrawals from storage and reserves during 1934 were approximately 200,000,000 bbl., which is an alarming rate, considering the small reserves of the state and dearth of new discoveries.

Even though completions were more numerous during the year than in any of the previous three years, additional reserves thereby created were inadequate to offset withdrawals from the reserves established prior to 1934. In certain instances deeper drilling and testing in proved fields indicated that the estimated reserves for these fields were much too high, this condition being especially true of the Inglewood, Dominguez and Montebello fields.

With the approval of the Oil Administrator and the Department of Justice at Washington, the Pacific Coast Petroleum Agency was formed during the month of June. Signatories to the pact agreed not to produce, buy or utilize any crude oil in excess of the amount prescribed by the Petroleum Administrator. The duty of the Agency is to purchase any and all gasoline that cannot be sold by refiners in the regular course of their business, thus relieving the market of former surpluses. The establishment of this Agency immediately effected a decided drop in excess production and during the next few months overproduction was at a minimum. However, toward the close of the year one signer of the agreement and certain of those who had not signed the pact began to ignore curtailment orders and excess production increased considerably.

New Developments in Proved Areas

Edison.—This field was discovered by L. C. Osborne, through the completion of a 50-bbl. producer in November, 1931, at a depth of 1949 ft. In January, 1934, A. L. Jergins deepened this discovery well and obtained 120 bbl. per day of 14° gravity oil from a depth of 2300 ft. This recompletion started a leasing and drilling campaign, which defined the field with a probable proved area of 2000 acres and 60,000,000 bbl. reserve.

Two zones, the Chanac and Temblor, were developed. The structure is a southwest-dipping monocline, producing very heavy oil updip at shallow depths. The Temblor zone is sealed on the east by a northwest-trending ridge. The Chanac (Lower Kern River) is sealed by overlapping. The productive formations thicken to the southwest and edge wells downdip produce a 30° gravity oil from the Temblor.

Inglewood.—A deep zone, known to be productive but not completely explored, was recently opened by Pacific Western Oil Co. in the Inglewood field. This zone, known as the Rindge, was first discovered some years

TABLE 1.—*Oil and Gas Production in California*

Line Number	Field Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres			
				Oil	Oil and Gas[a]	Gas	Total
1	1	Alamitos, *Los Angeles*	7¾		110		110
2	2	Athens-Rosecrans, *Los Angeles*	10¾		310		310
3	3	Brea-Olinda, *Orange*	54		1,410		1,410
4	4	Dominguez, *Los Angeles*	11⅓		665		665
5	5	Coyote East, *Orange*	23¼		785		785
6	6	Coyote West, *Orange*	29		930		930
7	7	Huntington Beach, *Orange*	14⅓		1,845		1,845
8	8	Inglewood, *Los Angeles*	10⅓		865		865
9	9	Lawndale, *Los Angeles*	6½	13			13
10	10	Long Beach, *Los Angeles*	13½		1,305		1,305
11	11	Los Angeles—Salt Lake, *Los Angeles*	31¾		990		990
12	12	Montbello, *Los Angeles*	17⅚		1,078		1,078
13	13	Playa Del Rey, *Los Angeles*	5		320		320
14	14	Potrero, *Los Angeles*	7⅓		113		113
15	15	Richfield, *Orange*	15⅚		1,278		1,278
16	16	Santa Fe Springs, *Los Angeles*	15⅙		1,138		1,138
17	17	Seal Beach, *Los Angeles*	8½		330		330
18	18	Torrance-Redondo, *Los Angeles*	12½		3,835		3,835
19	19	Whittier, *Los Angeles*	32⅔		575		575
20	20	Capitan, *Santa Barbara*	5¼	200			200
21	21	Elwood, *Santa Barbara*	6½		400		400
22	22	Gato Ridge	3½	1,620			1,620
23	23	Moore Ranch, *Santa Barbara*	5			Gas	*y*
24	24	Rincon, *Ventura*	7¼		350		350
25	25	San Miguelito, *Ventura*	4⅓		300		300
26	26	Santa Barbara, *Santa Barbara*	5¾	50			50
27	27	Santa Maria, *Santa Barbara, San Luis Obispo*	32⅙		10,687		10,687
28	27-A	Casmalia, *Santa Barbara*	17⅙	1,130			1,130
29	27-B	Cat Canyon-East, *Santa Barbara*	23½	} 1,187			} 1,187
30	27-C	Cat Canyon-West, *Santa Barbara*	23½				
31	27-D	Edna (Arroyo Grande), *San Luis Obispo*	24⅔	270			270
32	27-E	Huasna, *San Luis Obispo*	5	*y*			*y*
33	27-F	Lompoc, *Santa Barbara*	30½	2,780			2,780
34	27-G	Orcutt, *Santa Barbara*	32⅙		4,620		4,620
35	28	Summerland, *Santa Barbara*	42	120			120
36	29	Ventura Avenue	18¼		1,760		1,760
37	30	Ventura-Newhall, *Ventura, Los Angeles*	70	4,685			4,685
38	30-A	Bardsdale, *Ventura*	40				
39	30-B	Conejo, *Ventura*	40				
40	30-C	Elsmere Canyon, *Los Angeles*	45				
41	30-D	Ex-Misson, *Ventura*					
42	30-E	Hopper Canyon, *Ventura*	47				
43	30-F	Modelo, *Ventura*	36				
44	30-G	Newhall, *Ventura*					
45	30-H	Pico Canyon, *Los Angeles*	59				
46	30-I	Sespe Canyon, *Ventura*	33				
47	30-J	Shiells Canyon, *Ventura*	23				
48	30-K	Simi Susanna, *Ventura*	22				
49	30-L	Sisar Silverthread, *Ventura*	49				
50	30-M	South Mountain, *Ventura*	18 7/12				
51	30-N	Sulphur Mountain, *Ventura*	7				
52	30-O	Tapo-Eureka, *Ventura*	24				
53	30-P	Temescal, *Ventura*	10				
54	30-Q	Timber Canyon, *Ventura*	49				
55	30-R	Tiptop Fresno Canyon, *Ventura*	16				
56	30-S	Torrey Canyon, *Ventura*	38				
57	30-T	Wiley, *Los Angeles*	47				
58	31	Watsonville, *San Mateo, Santa Barbara, Santa Clara*	48				
59	31-A	Hala Moon Bay, *San Mateo*	48				
60	31-B	Los Gatos, *Santa Barbara*	*y*				
61	31-C	Sargent, *Santa Clara*	*y*				
62	32	Belridge, *Kern*	23¾				
63	32-A	Belridge, North-Deep, *Kern*	4¼		3,720		3,720
64	32-B	Belridge, North-Shallow, *Kern*	22½		1,030		1,030
65	32-C	Belridge, South, *Kern*	23¾		1,520		1,520
66	33	Coalinga-East, *Fresno*	34		5,320		5,320
67	34	Coalinga-West, *Fresno*	33	9,110			9,110
68	35	Coffee Canyon, *Kern*	1¾	220			220
69	36	Edison, *Kern*	3¼		3,000		3,000
70	37	Elk Hills, *Kern*	16	0	9,850		9,850
71	38	Fruitvale, *Kern*	6¾	1,220			1,220
72	39	Kern Front, *Kern*	22½	3,050			3,050
73	40	Kern River, *Kern*	34½	6,973			6,973
74	41	Kettleman Middle, *Kings*	3		1,280		1,280

[a] Footnotes to column headings and explanation of symbols are on page 249.

ago by the Associated Oil Co. Eight wells have been completed during 1934 in the Rindge zone with initials ranging from 300 to 2100 bbl. per day. The Pacific Western Oil Co. also discovered a zone below the Rindge, which includes formations between 3300 and 5000 ft. on top of the structure. Their Rubel No. 17 well was completed in this zone for an initial of 2000 bbl. per day of 32° gravity clean oil. Developments in both the Rindge and Rubel zones indicate that their extensiveness will not be as great as expected and certainly will not be as extensive as the upper Machado-Vickers zone.

Kettleman Hills North Dome.—Because of pressure decline over the entire structure by withdrawals of oil and gas mostly from the north plunge of this field, and the necessity for defining the productive limits of the field for the purpose of determining the final participation acreage in the unit plan of development, increased drilling was experienced during 1934. Classification of acreage as of Jan. 31, 1934 showed 16,370 acres inside of the purple line, or a decrease of 1240 acres from the brown line of the previous year.*

Deeper drilling has indicated that on top of the structure the thickness of the productive horizon is at least 2000 ft., although the deeper sands will not be as prolific as upper formations. Completions in the "gas-cap" area on top of the structure have been very small compared to the large potentials obtained in the "black-oil" area on the edges of the structure.

The productive area on the south end of the field will be very narrow and completions will be small compared to the wells drilled on the north plunge.

TABLE 1.—(*Continued*)

Line Number	Field Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres			
				Oil	Oil and Gas[a]	Gas	Total
75	42	Kettleman-North, *Kings, Fresno*	6¼		16,370		16,370
76	43	Lost Hills, *Kern*	24¾	2,310			2,310
77	44	McKittrick, *Kern*	37	1,710			1,710
78	45	Midway-Maricopa, *Kern*	33½		48,600		48,600
79	46	Mountain View, *Kern*	1½		1,600		1,600
80	47	Mount Poso, *Kern*	8 7/12	1,360			1,360
81	48	Premier, *Kern*	8	750			750
82	49	Round Mountain, *Kern*	7¼	901			901
83	50	Wheeler Ridge, *Kern*	12⅙	320			320
84	51	Buttonwillow, *Kern*	5			750	750
85	52	Tulare Lake, *Kern*	5			1,900	1,900
86	44-A	Devils Den, *Kern*	25				*y*
87	45-A	McVan	2⅚				*y*
88	45-B	Pyramid Hills					*y*
89		Terra Bella, *Tulare*	4½				*y*
90		Total, *California*					

[a] Footnotes to column headings and explanation of symbols are on page 249.

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* The significance of the colors is: blue line, maximum area of participation; red line, irreducible minimum area; brown line, limit of productive acreage as determined by Engineering Committee, February, 1933; purple line, ditto, February, 1934; Orange line, ditto, April, 1935.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production			
	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	Millions Cu. Ft.			Maximum Daily during 1934, M Cu. Ft.
								To End of 1934	During 1933	During 1934	
1	[1]	833,380	793,506	1,989	[1]			[1]	[1]		
2	29,375,058	1,080,247	1,037,817	2,973	94,758			47,540	2,071	1,756	326
3	150,586,027	2,964,674	3,744,538	10,652	106,799			69,359	3,478	3,645	11,400
4	69,843,912	6,626,605	6,655,465	18,217	105,028			105,815	10,940	11,148	35,000
5	74,309,954	579,853	907,334	2,636	94,662			34,834	2,447.4	3,298	
6	65,217,543	3,118,519	3,236,702	8,851	70,126						7,720
7	217,662,713	13,091,926	15,106,268	39,239	117,974			202,518	12,333	26,281	86,850
8	92,055,649	4,059,973	3,376,586	9,525	106,423			72,081	1,077	1,461	5,170
9	365,120	79,460	53,640	127	28,086			988	185	138	330
10	525,245,147	24,798,242	23,067,025	60,790	402,487			743,060	27,314	20,730	62,800
11	64,557,151	313,810	289,154	809	65,209			y			
12	95,037,855	1,933,121	1,980,942	5,734	88,161			21,012	319	313	1,180
13	27,662,059	4,059,240	3,187,773	9,476	96,444			25,768	4,887	2,403	9,230
14	1,915,309	141,791	150,084	430	16,950			1,846	31		
15	74,716,340	2,467,913	2,925,001	8,145	58,463			67,896	3,060	2,553	7,500
16	385,619,474	18,271,807	14,722,264	38,860	338,857			606,089	18,659	13,520	40,600
17	68,805,470	3,158,521	2,721,951	6,270	156,376			76,856	3,294	3,570	12,680
18	77,714,433	2,362,719	2,525,990	6,874	20,265			56,351	1,343	1,271	3,720
19	16,266,606	404,128	393,476	1,123	28,290			366	23		
20	303,400	24,621	194,414	616	1,517						
21	49,967,632	4,918,488	4,113,644	9,920	124,919			42,820	2,478	1,392	5,520
22	(31,084)		(31,084)								
23		Gas						5,034	1,505		
24	5,843,813	680,471	540,886	1,528	16,697			6,009	522	430	1,320
25	935,698	390,559	268,643	618	3,119						
26	1,138,616	249,426	598,165	4,329	24,772						
27	131,580,922	1,254,818	1,806,106	4,939	12,312			28,905	1,612	1,814	5,200
28	x	y	(73,746)	(96)				20		20	
29	x							y	y	2	7
30	x	y	(113,186)	(274)							
31	x	y	(37,339)	(108)							
32	x	y	y	y							
33	x	y	(44,550)	(218)							
34	x	y	(1,470,783)	(41,200)							
35	3,096,480	31,434	20,039	44	25,804						
36	152,244,008	12,576,208	9,882,614	24,372	86,502			562,308—	38,963	39,507	123,000
37	52,497,211	1,199,997	1,400,039	3,970	11,205			y	1,868	y	y
38	x	y	(16,751)	(44)							
39	x										
40	x										
41	x	y	(14,398)	(35)							
42	x	y	(40,235)	(111)							
43	x	y	y	y							
44	x	y	(61,514)	(165)							
45	x	y	(23,650)	(65)							
46	x	y	(93,819)	(220)							
47	x	y	(141,005)	(397)							
48	x	y	(40,887)	(115)							
49	x	y	(57,443)	(133)							
50	x	y	(720,991)	(2,080)				42,466	y	2,464	7,120
51	x	y	(5,439)	(19)							
52	x	y	(12,762)	(53)							
53	x	y	(53,010)	(166)							
54	x	y	(19,233)	(51)							
55	x	y	(6,306)	(16)							
56	x	y	(54,590)	(154)							
57	x	y	(7,151)	(18)							
58	89,518	21,999	21,900	60							
59	x										
60	x										
61	x										
62		(2,867,079)						33,644	5,806	5,217	16,400
63	8,005,601	1,967,000	2,170,601	5,327	2,152						
64	15,835,605	900,079	22,171	10	15,835						
65	19,054,864	4,423,512	734,864	1,913	12,536						
66	333,296,027		4,255,861	12,100	62,650			1,014	266	43	
67			2,339,089	6,415							
68	With Round Mountain	With Round Mountain	613,475	1,389							

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[1] With Seal Beach.

Developments to date tend to decrease early estimates of reserves in this field.

Lost Hills.—Associated Oil Co. suspended its deep test in this field at a depth of 7858 ft. without favorable results. The well was drilled on the east flank of the structure because of supposed asymmetry of the axis to the east. Results obtained indicate that the structure is a tightly compressed fold, with slight asymmetry to the west. Without doubt further drilling will be commenced during 1935, to discover the Wagon Wheel zone (Eocene), which is so prolific in the neighboring North Belridge field.

Long Beach.—Drilling activity at Long Beach continued at its usual high rate. Very favorable completions were obtained because of better knowledge of underground conditions, electrical coring, formation testing, directed drilling and isolating small saturated sand bodies, which were not drained by the great penetrations of wells drilled in earlier days.

Montebello.—Owing to the discovery of a deep Miocene zone by the Universal Oil Co. in this field during 1933, there was considerable drilling activity during 1934. Results obtained indicate that the Miocene structure is unconformable to the Pliocene structure and probably will extend eastward from the east edge of the old field. Of 14 wells started for the new zone, only three obtained small production from the Miocene. Further drilling is contemplated in order to define the limits of the

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production			
								Millions Cu. Ft.			
	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934, M. Cu. Ft.
69	135,792		135,792	938	45						
70	131,963,700	4,487,978	3,345,772	7,889	13,397			82,027	1,390	917	2,820
71	7,115,317	1,672,805	1,342,724	3,744	5,832						
72	30,434,866	2,340,103	2,434,866	6,728	9,979						
73	265,802,413	869,907	1,269,581	3,820	38,119						
74	290,514	151,979	127,998	625	227			7,092	3,270	3,822	17,900
75	90,592,663	21,472,041	21,265,884	58,403	5,534			749,018	104,426	115,729	350,500
76	32,382,803	338,794	1,463,453	4,561	14,019				With Belridge		1,400
77	83,568,039	651,361	1,105,618	3,012	48,870						
78	764,571,504	17,541,812	19,712,566	51,946	15,732			278,599	16,804	16,284	46,830
79	2,842,358	233,341	2,609,017	11,676	1,776			1,810	80	1,730	9,100
80	18,258,490	3,050,826	3,486,217	10,235	13,425				2.4		
81	(62,136)		(62,136)	(250)	82						
82	5,573,196	1,118,913	1,194,847	3,580	4,972						
83	3,067,242	168,918	156,204	419	9,585						
84	Gas							4,065	18.6		
85	Gas										
86	x	y	(2,927)								
87	x	y	(9,034)	(12)	x	x					
88	x	y	(4,845)		x	x					
89	x	y	y	y	y		y				
90	4,247,444,112	173,083,319	175,508,566	477,846				3,977,210	270,472	281,458	871,623

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells								Average Depth, Ft.		Character of Oil Approx. Average during 1934		
	Completed to End of 1934	During 1934		At End of 1934							Gravity A.P.I. at 60° F.		
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Capable Producing	Bottoms of Productive Wells	To Top of Productive Zone	Maximum	Minimum	Weighted Average
1	[1]	1		4		53		57	5,700	4,610	30	23	26
2	204		3	18		70		88	5,150	3,700	*y*	*y*	40
3	622	2	2	52		352		404	2,821	1,200	31	16	26
4	167	27		62		71		133	4,410	3,750	43	26	27
5	384	3		17		76		93	3,615	2,450	28	18	21
6		9	1	104		25		129	4,191	2,900 4,000 2,800 3,300 4,200	28	18	21
7	1,095	28	15	154		469		623	3,994 4,042	1,900	27	11	23
8	286	8	1	40		206		246	2,490	1,100	29	13	20
9	7		2	0		6		6	5,850	5,750	31	22	31
10	1,942	83	12	156		1,091		1,247	5,575	2,300	31	17	25
11	1,617		39	30		126		156	1,083	*y*	22	12	15
12	246	9	2	41		160		201	3,219	1,800	30	17	23
13	246	6	7	27		160		187	5,086	3,500 5,500	26	20	24
14	33		2			12		12	5,730	3,700	45	34	38
15	399		6	36		249		285	4,149	2,200	30	14	21
16	1,020	16	17	186		492		678	5,480	3,300	36	27	32
17	233	1	1	25		57		82	5,396	4,300 3,500 3,100	30	23	26
18	880		6	40		474		514	3,682	2,700	27	11	19
19	290			13		159		172	2,082	250	24	13	20
20	16	5		2		13		15			43	19	*y*
21	84	9	1	14		51		65	3,368	3,164 4,325	37	30	*y*
22	*y*	*y*		2				2	2,887	*y*	17	14	15
23	*y*	*y*							*y*	*y*			
24	46	1		6		30		36	3,635	2,900	29	25	*y*
25	4	1		0		3		3	7,597	6,470	28	22	*y*
26	61	39	4	0		52		52	1,300 2,700	2,036	*y*	*y*	19
27	522	5	5	235		187		422	3,250	*y*	25	10	*y*
28	*y*	*y*	*y*						1,900	*y*	*y*	*y*	*y*
29	*y*	*y*	*y*						3,200	*y*	*y*	*y*	*y*
30	*y*	*y*	*y*						2,950	*y*	*y*	*y*	14
31	*y*	*y*	*y*						1,148	*y*	*y*	*y*	14
32	*y*	*y*	*y*						1,500	*y*	*y*	*y*	*y*
33	*y*	*y*	*y*						2,663	*y*	*y*	*y*	19
34	See Santa Maria								3,250	1,200	*y*	*y*	17
35	323	1		1		17		18	1,088	*y*	19	12	*y*
36	340	12	6	94		178		272	6,450	*y*	30	24	*y*
37	1,282	7	15	245		464		709			40	12	*y*
38									923		*y*	*y*	*y*
39									100		*y*	*y*	*y*
40									719		*y*	*y*	*y*
41									1,312		*y*	*y*	*y*
42									1,365		*y*	*y*	12
43									2,050		*y*	*y*	*y*
44									1,233		*y*	*y*	40
45									1,612		*y*	*y*	*y*
46									1,170		*y*	*y*	*y*
47									602 2,700				
48									1,200		*y*	*y*	*y*
49									1,200		*y*	*y*	*y*
50									3,345		*y*	*y*	16
51									2,500		*y*	*y*	*y*
52									969		*y*	*y*	*y*
53									2,211		*y*	*y*	*y*
54									2,384		*y*	*y*	*y*
55									740		*y*	*y*	*y*

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[1] With Seal Beach.

Miocene production and it is expected that some favorable completions will be obtained.

Mountain View.—The greatest drilling activity in California was centered in this field during 1934. Plans of Orderly Development were approved by the Secretary of the Interior, with a well-spacing program of one to each 10 acres. This field, which is a complicated faulted monocline, was extended a considerable distance to the northwest, and drilling activity in the northwest portion of the field added approximately 500 proved acres. The oil is produced wholly by force of water, the gas-oil ratios being practically constant at all rates of flow. The present proved area comprises approximately 1600 acres, with an estimated total reserve of 45,000,000 bbl. The field at present is about 5 miles long and ½ mile wide, and developments indicate that it will be extended both

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells								Average Depth, Ft.		Character of Oil Approx. Average during 1934		
	Completed to End of 1934	During 1934		At End of 1934							Gravity A.P.I. at 60° F.		
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Capable Producing	Bottoms of Productive Wells	To Top of Productive Zone	Maximum	Minimum	Weighted Average
56									1,363		*y*	*y*	*y*
57									968		*y*	*y*	*y*
58	27			0		7		7			17	10	*y*
59									1,200		*y*	*y*	*y*
60									1,200		*y*	*y*	*y*
61									1,500		*y*	*y*	*y*
62											*y*	*y*	*y*
63	820	4	1						5,457	4,900	*y*	*y*	*y*
				13		23		36	8,563	8,000			
64			1						4,000	*y*	*y*	*y*	*y*
65				123		140		263	892	*y*	*y*	*y*	*y*
66	1,901	1	7	279		332		611	2,087		*y*	*y*	*y*
67				122		620		742	1,614		*y*	*y*	*y*
68	With Round Mt.			0		30		30	1,662		17	16	16
69	14	11	1	0		14		14	2,750		*y*	*y*	16
70	368		1	124		168		292	3,026		38	15	*y*
71	81	8	4	11		67		78	3,956		22	15	*y*
72	With Kern River	5		42		281		323	2,195		16	12	*y*
73	3,148		7	1,070		1,104		2,174	767		16	12	14
74	2	1		0		2		2	7,900		*y*	*y*	57
75	110	41		29		75		104	8,240	6,070	64	33	*x*
76	With Belridge			65		315		380	1,430		27	14	*x*
77	548	2	2	126		184		310	1,177		15	11	*x*
78	4,306	11	26	1,005		2,478		3,483	2,004	*y*	28	11	*x*
79	58	49		0		50		50	5,898	5,810	34	24	28
80	197	44	2	18		152		170	1,703	*y*	16	15	15
81	*y*	*y*		3		4		7	2,769	*y*			
82	68	3		20		19		39	1,921	*y*	17	16	16
83	38			0		34		34	2,716	*y*	23	22	22
84	20								2,750	*y*			
85	3		1						1,200	*y*			
86	*y*	*y*		*y*	*y*	*y*	*y*	*y*	1,330	*y*	*y*	*y*	18
87	*y*	*y*		*y*	*y*	*y*	*y*	*y*	1,192	*y*			
88	*y*	*y*		*y*	*y*	*y*	*y*	*y*	*y*	*y*			
89	*y*	*y*		*y*	*y*	*y*	*y*	*y*	925	*y*			
90	24,058	453	200	4,654		11,402		16,056					

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934		Estimated Gross Oil Reserves Jan., 1934
	Name	Age^g	Character^h	Porosity^i	Net Thickness, Average Ft.	Structure^j		Name	Depth of Hole, Ft.	
1	Pico Puente	Pli Mio	SH		2,300	AF			9,054	
2	Pico	Pli	SH		1,200	A			7,591	6,500
3	Puente	Mio	SH		2,500	AF			8,201	41,200
4	Pico	Pli	SH		2,000	A			8,992	63,500
5	Pico Puente	Pli Mio	SH		800	A			9,084	13,593
6	Pico Puente	Pli Mio	SH		2,000	A			8,144	36,763
7	Pico Puente	Pli Mio	SH		1,500	MF			9,054	65,000
8	Pico	Pli	SH		2,000	AF		Rubel	5,025	71,500
9	Puente	Mio	SH		700	Sand lenses				250
10	Pico Puente	Pli Mio	SH		5,600	AF			9,280	157,000
11	Pico Puente	Pli Mio	SH		2,000	AF				1,700
12	Pico Puente	Pli Mio	SH		2,500	AF		Cruz	8,265	23,800
13	Pico Puente	Pli Mio	SH		1,200	A			6,778	25,000
14	Pico	Pli	SH		400	AF				1,270
15	Pico Puente	Pli Mio	SH		1,500	A			5,933	17,000
16	Pico Puente	Pli Mio	SH		3,200	A			9,610	70,000
17	Pico Puente	Pli Mio	SH		2,000	AF			7,969	26,500
18	Pico Puente	Pli Mio	SH		400	A			5,938	12,500
19	Pico	Pli	SH		3,000	MF			5,040	2,100
20	Vaqueros Sespe	Mio Olig	SH			A			4,071	11,800
21	Vaqueros Sespe	Mio Olig	SH			AF				52,000
22	Monterey	Mio	SH			Broken shale			2,510	32,000
23	Vaqueros	Mio	SH			AF			6,912	
24	Pico	Pli	SH			AF			7,449	4,950
25	Pico	Pli	SH			AF			10,030	29,731
26	Vaqueros	Mio	SH			MF			3,630	5,400
27										46,200
28	*y*	Mio	SH			A				
29	*y*	Pli	SH			A				
30	*y*	Pli	SH			A			7,199	
31	*y*	Mio	SH			S				
32	*y*	Mio	SH			S				
33	*y*	Mio				AF				
34	*y*	Mio	SH			AF			5,815	
35	Fernando Vaqueros	Pli Mio	SH			AF			5,041	330
36	Pico	Pli	SH			D			9,710	145,100
37	*y*	*y*	*y*			*y*				16,600
38	Sespe	Olig				A				
39	Vaqueros Fernando	Mio Pli				T				
40	Vaqueros	Mio				A				
41	*y*	*y*	*y*			*y*				
42	Monterey Vaqueros	Mio				S				
43	Monterey Vaqueros	Mio				A				
44	*y*	*y*				*y*				
45	*y*	Mio				A				
46										
47	Sespe	Olig				A		Eoc	5,425	
48	Sespe	Olig								
49	Monterey Sespe	Mio Olig				AF				

southeasterly and northwesterly and that there may be lateral extensions also.

North Belridge.—Since the approval of the Orderly Plan of Development for the Wagon Wheel zone by the Secretary of the Interior, drilling of this zone has proceeded in a very gradual manner. One well was completed during the year and another encountered edge water and is being plugged back. Reserves of both oil and gas are second only to Kettleman Hills. Developments indicate that the gas cap covers a

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934		Estimated Gross Oil Reserves Jan., 1934
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average, Ft.	Structure[j]		Name	Depth of Hole, Ft.	
50	Sespe	Olig				A				
51	Montery	Mio				A				
52	Meganos	Eoc				A				
	Vaqueros	Mio								
53	Vaqueros	Mio				A				
54	Vaqueros	Mio								
55	Montery	Mio								
	Sespe	Olig								
56						A				
57	[y]	Mio				A				
58										353
59										
60										
61	[y]	Mio				MF				
62										
63	Temblor	Mio	SH			A				212,808
	Wagon Wheel	Eoc								
64	Etchegoin	Pli	SH			A				
65	Etchegoin	Pli	SH			A		Mio	11,377	7,265
		Mio								
66	Temblor	Mio	SH			A				63,405
67	Jacilotos	CreU								
	Temblor	Mio	SH			MUP				
	Santa Margarita	Mio								
68	Vaqueros	Mio	SH			FM				7,387
69	Chanac	Pli	SH			M		Lower Zone	3,200	59,866
	Santa Margarita	Mio								
	Temblor									
70	Etchegoin	Pli	SH		300	A				211,654
	Kern River									
71	Etchegoin	Pli	SH		500	MF				33,657
72	Etchegoin	Pli	SH		275	MF				33,566
73	Kern River	Pli	SH		450	MF			5,135	16,370
74	Temblor	Mio	SH		300	A			9,332	39,850
75	Temblor	Mio	SH		1,100	A			10,944	900,000
76	Etchegoin	Pli	SH		300	A			7,858	11,537
77	Etchegoin	Pli	SH		200	AF			6,664	8,095
78	Etchegoin	Pli								
	Santa Margarita	Mio			2,000	MC			9,753	173,000
	Maricopa	Mio	SH							
79	Kern River	Pli								
	Santa Margarita	Mio	SH		260	MF			8,419	42,390
80	Vaqueros	Mio	SH		280	MF			3,130	45,000
81	Etchegoin	Pli	SH			MF				14,800
82	Vaqueros	Mio	SH		480	MF			3,763	38,805
83	Maricopa	Mio	SH		600	A			7,154	554
84	Tulare									
	Etchegoin	Pli	SS		100	D			4,946	
85	Tulare	Mio	S		150	H			4,310	
86	Kreyenhagen	Olig	S		[y]	[y]				
87										
88										
89										
90										2,899,649

very considerable area, and that, as at Kettleman Hills, wells with low gas-oil ratio can be obtained only by drilling on edge properties. Developments at Kettleman Hills indicate that the great recoveries per acre obtained in the water-drive fields of the Los Angeles Basin and on the east side of the San Joaquin Valley will not be obtained in large fields of the state that have gas caps.

Playa del Rey.—The completion of a well by Charles W. Fourl at a 5000-bbl.-per-day rate of 24° gravity clean oil from below 6500 ft. extended this field approximately ½ mile easterly and caused a brisk leasing campaign. The magnitude of this producer was extremely surprising, as wells along the easterly plunge of this field have never exceeded a 1000-bbl.-per-day initial rate. The prolific nature of the zone is accounted for by the thickening of the conglomerate beds in all directions away from the schist high, beneath the apex of the fold, and as the Fourl well is about a mile from this high it could include the extra thickness of productive horizon prevalent at its location. Approximately 10,000,000 bbl. of new reserves was added to this field through the proving of about 300 additional acres by the aforementioned completion.

Santa Barbara.—Approximately 50 new wells were drilled to completion in the newly discovered prolific area of this field during 1934, and, although the area appears badly faulted, initials ranged in some instances between 800 and 2000 bbl. per day. Production is obtained from the Vaqueros formations around 2000 ft. Although wells decline rapidly, the small cost of their drilling makes them profitable ventures. There is a probability that the Sespe may also be productive, in which case the field will enjoy a much longer life than it has been allotted. During 1934 this field produced around 600,000 bbl. of oil, which is more than was produced during the five years since discovery in 1929.

South Belridge.—The General Petroleum Corporation established a record feat in drilling its Berry No. 1 well to a depth of 11,377 ft. This well obtained negative results because it was unfavorably located, which was discovered too late for correction. This field is still considered a good prospect for deep zone production.

Progress in Orderly Plans of Development.—Inasmuch as all newly discovered fields and pools in California are not apportioned allotments until a plan of orderly development has been approved by the Secretary of the Interior, many meetings were held during 1934 for the purpose of formulating these plans. By the end of the year 19 plans had received the approval of the Secretary, of which 13 were approved in 1934. All of the plans are terminable at the expiration of the Code of Fair Competition in June, 1935, but may be continued in force at the discretion of a majority of the operators controlling production in their respective pools or fields.

Geophysical Prospecting and Results Obtained.—Geophysical prospecting was given a tremendous impetus during 1934, even to the extent of endeavoring to determine true conditions of proved structures. Three gas fields were discovered as a direct result of seismograph reflection shooting, one at Chowchilla, in the western portion of the San Joaquin Valley, by the Pure Oil Co., one at Buena Vista Lake by the Ohio Oil Co. and the third by the Trico Oil Co. at Tulare Lake. The extent of these discoveries is as yet unknown but is interesting because they are the first successful results obtained from geophysical methods of prospecting in California. The Pure Oil Co. discovery well was completed from below 8000 ft. for 20,000,000 cu. ft. of gas per day and constitutes the first commercial gas production obtained from the Cretaceous beds in California. No oil discoveries were made in 1934 through drilling on structures located by geophysical prospecting, although numerous wildcats were started and many were engaged in drilling on these structures toward the close of the year.

CONCLUSION

There is every indication that California will receive a larger oil allotment during the year 1935. Allotments to date have been on the basis of gasoline demand, but under this system fuel-oil stocks were drawn on during the year at the approximate rate of 70,000 bbl. per day. To eliminate withdrawals from storage, it will be necessary to cut curtailment on heavy-oil production to a minimum. During 1934, stocks of refinable crude as well as motor fuel showed a slight increase.

Because there have not been any major discoveries of new fields in California over a long period, or since the discovery of Kettleman Hills in 1929, withdrawals have exceeded additions to reserves; therefore greater drilling activity and a possible price increase in crude is anticipated during 1935.

Oil and Gas Development in Colorado in 1934

By C. E. Shoenfelt,* Member A.I.M.E.

Operations in Colorado oil fields in 1934 were not quite so extensive as in 1933, but much better results were obtained and one new oil field was discovered. In all, 26 wells were drilled, of which 9 were oil wells, 1 was a gas well, and 16 were dry holes. New oil production totaled 10,220 bbl. and new gas production totaled 33,714,000 cu. ft. This compares with new oil production in 1933 of 1238 bbl. and new gas production of 14,307,000 cu. ft. Dry holes in 1933 totaled 29 as compared with 16 in 1934.

Oil was discovered in the Hiawatha gas field, Moffat County, in 1934 in the Mountain Fuel Supply Company's No. 4B Wilson, C. NE. NW. of sec. 23, 12N., 100W. This well was completed in a sand in the Wasatch (Tertiary) at 2304 to 2337 ft., after plugging back from 3797 ft. It made 20 bbl. of oil initially.

No. 4B Wilson is the first well in the Rocky Mountain region to discover oil in commercial amounts in rocks younger than Cretaceous, and while it is not expected that Hiawatha will develop into an oil field of important proportions, eventually it may produce a considerable amount of oil as the gas pressure declines.

The Hiawatha gas field was discovered in 1926, on one of six structures in what is known as the Vermillion Creek gas area. It is a northeast-

Table 1.—*Oil and Gas Production in Colorado*

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres		
			Oil	Gas	Total
1	Berthoud, *Larimer*	5	510		510
2	Boulder, *Boulder*	32	400		400
3	Florence-Canon City, *Fremont*	73	9,000		9,000
4	Ft. Collins, *Larimer*	11	400		400
5	Garcia, *Las Animas*	8		640	640
6	Greasewood, *Weld*	4	200		200
7	Hamilton (Moffat), *Moffat*	11	400		400
8	Hiawatha, *Moffat*	7		3,180	3,180
9	Iles, *Moffat*	10	600		600
10	Mancos Creek, *Montezuma*		40		40
11	Model, *Las Animas*	6		2,000	2,000
12	Rangely, *Rio Blanco*	15	320		320
13	Tow Creek, *Routt*	10	200		200
14	Walden, *Jackson*	7	320		320
15	Wellington, *Larimer*	10	1,000		1,000
16	Total		13,390	5,820	19,210

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* Geologist, Petroleum Information, Inc., Denver, Colorado.

southwest structure with 235 ft. of local closure and embraces 4400 acres above the lowest closing contour. The Wasatch formation outcrops, and it is in this same formation that the several gas-bearing sands are found. The crest of the dome is practically unfaulted, but several faults are found in the synclines.

Seven gas wells with open-flow capacities of from 3,000,000 to 58,000,000 cu. ft., and with rock pressures of 600 to 800 lb., have been completed by the Mountain Fuel Supply Co. Several of these wells have made a few barrels of oil with the gas, and it was necessary as early as 1932 for the company to install drips at practically all of its wells to remove the oil before the gas could be turned into the Salt Lake line of the Western Public Service Corporation.

One of the most interesting tests in progress at the close of the year is the South Park Oil Company's drilling well on the Hartsel anticline in South Park, Park County. The well is on state land in the SW. SE. SE. of sec. 16, 11S., 75W., at an elevation of 9386 ft. above sea level.

The park-like area known as South Park is in the high mountains southwest of Denver and consists of two downthrown fault blocks between the Mosquito Range on the west and spurs of the Front Range on the east. It is a small area of sedimentary rocks completely surrounded by granite. The Hartsel anticline, in the east fault block, is a long, narrow northwest-southeast-trending structure upon which are a number of superimposed domes separated by shallow synclines or saddles. The structure occupies a narrow valley between two deep synclines lying east and west of and approximately parallel to the crest of the fold. The well starts in Fox Hills (Cretaceous) beds and has for objectives the various sands found in the Upper Cretaceous and in the Jurassic.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.			
	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934
1	33,854	5,163	4,760	13	66	3.3	4	385	85	56	*y*
2	610,606	5,840	6,391	18	1,526		2.6				
3	13,207,205	91,343	82,151	210	1,468		2				
4	1,991,767	49,870	38,132	107	4,979	199	10				
5								2,494	278	200	0.75
6	387,854	52,198	36,487	82	1,939	55	27				
7	4,894,385	204,242	162,746	520	12,829	641	43.3				
8								*y*	1,467	1,581	*y*
9	3,153,746	210,032	514,947	1,685	5,256	263	80				
10	2,874	715	606	2			0.7				
11								19	0	0	0
12	373,348	29,962	31,270	86	1,166		21				
13	1,342,550	86,949	71,723	164	6,713		14				
14	156,886	0	23,567	151	490	100	151				
15	4,347,183	176,223	148,412	359	4,347	217	16				
16	30,502,258	912,537	1,121,192								

[b] Footnotes to column heads and explanation of symbols are given on page 249.

One other test is worthy of mention. It is the Trojan Oil & Gas Company's No. 1 Lotus Oil, NW. NE. NE. of sec. 15, 23 S., 46 W., Prowers County. This well has been the center of interest in eastern Colorado for the past two years, not so much for its possibilities of

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells								Average Depth, Ft.		Oil Production Methods at End of 1934		Pressure, Lb. per Sq. In.[e]		
	Completed to End of 1934	During 1934		At End of 1934							Number of Wells		Initial	Average at End of	
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping		1933	1934
1	5	0	1			3	1	4	2,940	2,920		3	600	250	200
2	51	0	1		7			7		2,000		7			
3	1,202	0	2		105			105		2,200		105			
4	15	0	0		11			11	4,560	4,535		11			
5	14	0	0	1			8	8		1,600			12	6	5
6	8	0	0		3			3	6,680	6,645	3				
7	12	0	0		12			12	3,880	3,860		12			
8	10	2	0			1	9	10	Sand	lenses			850	850	830
9	28	5	0		23			23	3,315	3,295	11	12			
10	32	0	21	8	3			3		375		3			
11	6	0	0					0	1,004	960			25	12	12
12	50	0	0	1	4			4		600		4			
13	17	0	2		15			15		2,600		15			
14	2	0	0	1	1			1	5,115	5,110					
15	30	0	0		22			22	4,500	4,480		22			
16	1,482	7	27	11	206	4	18	238			14	194			

Line Number	Character of Oil Approx. Average during 1934				Character of Gas, Approx. Average during 1934		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Gravity A.P.I. at 60° F.														
	Maximum	Minimum	Weighted Average	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
1			385	P	1,120	0.9	Hygiene	CreU	S	20	20	A	4	Lakota (CreL)	4,031
2			386	P			Pierre	CreU	H			MF	44		
3			31	P			Pierre	CreU	H			T.S.	1,097	Fountain (Pen)	1,875
4	37	348		P			Muddy-Dakota	CreU	S	12	25	A	4	Dakota (CreU)	4,995
5					1,131	2.0	Benton	CreU	H			D	6	Morrison (Jur)	1,392
6			42	P			Muddy	CreU	S	9	35	A	5	Lakota (CreL)	6,913
7			41	P			Dakota	CreU	S	18[2]					
							Sundance	Jur	S	14	20	D		Sundance (Jur)	4,490
8					1,080		Wasatch		S	*y*	*x*	D		Mesaverde (CreU)	7,577
9			37	P			Mancos	CreU	H	9	20	D		Sundance (Jur)	3,447
							Sundance	Jur	S						
10			40	P											
11					Inert[1]		Santa Rosa	Tri	S	22	44	D	2	Fountain (Pen)	2,000
12	52	43		P			Mancos	CreU	H			A	45	Weber (Pen)	7,173
13			35	P			Mancos	CreU	H			A			
14			50	P			Muddy-Dakota	CreU	S	*x*[3]	5	AF	2	Muddy-Dakota	5,115
15			374	P			Muddy-Dakota	CreU	S	12	20	A	8	Morrison (Jur)	4,932
16															

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[1] 7.9 helium. At Thatcher, Colo., eleven miles distant, The Helium Co., of Louisville, Ky., has a $600,000 plant, temporarily shut down, for the extraction of helium from this gas.

[2] Figures from recovery indicate 20%.

[3] No samples of this sand have been recovered.

obtaining oil and gas production as because it is furnishing much valuable geological information in an area believed to be generally favorable for oil and gas production in Paleozoic rocks. The operators have announced that the well will be drilled to the Ordovician if production is not obtained in younger rocks.

The Lamar dome is a small elongated dome developed in Dakota sandstone, with about 30 ft. of closure. The drilling well found the top of the Pennsylvanian section at 2711 ft. and the top of the Mississippian at about 5010 feet.

TABLE 2.—*Summary of Drilling Operations in Colorado*
(Figures in body of tabulation represent number of holes)

County	Completed Prior to Jan. 1, 1935										Completed during 1934							Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes									Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes						Productive Wells (For Details, See Table 1)		
	Total Depths, Ft.										Total Depths, Ft.								
	0-1000	1000-2000	2000-3000	3000-4000	4000-5000	5000-6000	6000-7000	7000-8000	Total		0-1000	1000-2000	2000-3000	3000-4000	6000-7000	Total		Within Fields	Exploratory
Adams		2	1	2	0	1	0	0	6										1
Alamosa		0	2	1	0	0	0	0	3										
Arapahoe		4	1	0	0	1	1		7						1	1			
Archuleta		3	0	0	0	0	0	0	3										2
Baca		0	2	0	1	0	0	0	3										
Bent		0	0	1	1	0	1	0	3										
Boulder		5	32	14	4	2	2	1	60	7		1		1		2			
Cheyenne		2	0	0	0	1	0	0	3										
Crowley		4	0	0	0	0	0	0	4										
Delta		3	0	0	1	0	0	0	4										
Dolores		0	0	0	0	0	1	0	1										
Douglas		0	2	0	0	0	0	0	2										
Elbert		2	0	1	1	0	0	0	4										
El Paso		6	6	6	1	0	0	0	19				1			1			
Fremont		2	1252	3	1	0	0	0	1258	105			2	1		3			
Garfield		2	2	2	1	0	0	0	7										
Huerfano		1	4	3	0	0	0	0	8										2
Jackson		0	1	1	4	1	0	0	7										2
Jefferson		2	1	2	0	0	0	0	5										
Kiowa		3	1	0	0	0	0	0	4										
Kit Carson		0	0	1	0	0	0	0	1										
La Plata		5	2	5	0	0	0	0	12										
Larimer	2	9	10	8	46	2	0	0	77	37	2			1		3			
Las Animas		15	8	2	0	0	0	0	25									1	
Lincoln		0	3	1	0	0	0	0	4										1
Logan		0	0	0	1	1	0	0	2										
Mesa		5	2	3	0	0	0	0	10										
Moffit		5	20	44	10	1	0	1	81	45			3	6		9	7	3	
Montezuma	1	2	0	0	2	0	0	0	5		1					1			1
Montrose		0	0	2	1	1	1	0	5										
Morgan		1	0	0	0	1	2	0	4										
Otero		8	1	0	0	0	0	0	9										
Park		1	1	1	0	0	0	0	3				1	1		2			1
Prowers		1	5	0	0	1	0	0	7										1
Pueblo		8	5	2	0	0	0	0	15										1
Rio Blanco		2	4	2	3	3	0	1	15										
Routt		7	6	25	0	0	0	0	38			1		2		3			
Saguache		0	1	0	1	0	0	0	2										
Washington		5	1	0	1	0	0	0	7										
Weld		4	3	0	0	0	11	1	19	3					1	1			
Yuma		3	3	3	0	1	0	0	10										
Total	3	122	1382	135	80	17	19	4	1762	197	3	2	7	12	2	26	7	4	12

Oil and Gas Development in Illinois in 1934*

By Alfred H. Bell†

(New York Meeting, February, 1935)

Illinois produced 5 per cent more crude oil in 1934 than in 1933, because there was less curtailment, and the value of the year's production at the wells was 35 per cent more than that of the previous year. The average price of Illinois crude oil in 1934 was $1.13 as compared with $0.87 in 1933, an increase of 30 per cent.

The quotas of allowable production for Illinois during 1934, as authorized by Oil Administrator Harold L. Ickes, were as follows: January, February, March, 12,000 bbl. per day; April, May, 12,500; June, July, 12,600; August, 12,500; September, October, November, 12,000; December, 11,700. No other restrictions on production were in effect during the year until Oct. 11, when it was found necessary to prorate the fields to 75 per cent, a curtailment of 25 per cent below the quota fixed by the Federal Administrator. On Dec. 1 the curtailment was reduced to 18 per cent and on Dec. 18, to 15 per cent.

Production in Illinois by months during 1934 was as follows:

	Barrels		Barrels
January	393,000	July	394,000
February	337,000	August	402,000
March	394,000	September	378,000
April	373,000	October	352,000
May	411,000	November	305,000
June	392,000	December	321,000
		Total	4,452,000

In spite of higher prices for crude oil, fewer wells were drilled in Illinois in 1934 than in 1933 (Tables 1 and 2). Of the 26 wells drilled, 10 were oil producers, 8 were in proved fields and 2 were in a new pool in Wabash County, 1½ miles south of the nearest production, one was a small gas well on the Stubblefield anticline in Bond County, one was an input well for repressuring in the Colmar-Plymouth field, McDonough County, and 14 were dry holes, mostly scattered wildcat tests.

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TABLE 1.—*Oil and Gas Production in Illinois*

Line Number	Field, *County*	Age in Years to End of 1934	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil + Oil and Gas	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934
1	Warrenton-Borton, *Edgar*	28	100	0	100	26,000±	730±	730±	2
2	Westfield (Parker Twp.), *Clark, Coles*	30	9,000	50	9,050	*x*	*x*	*x*	*x*
3			850	70	920	*x*	*x*	*x*	*x*
4			9,000	0	9,000	*x*	*x*	*x*	*x*
5			1,500	0	1,500	*x*	*x*	*x*	*x*
6	Siggins (Union Twp.), *Cumberland, Clark*	28	3,580	75	3,655	*x*	*x*	*x*	*x*
7			3,135	55	3,190	*x*	*x*	*x*	*x*
8			435	15	450	*x*	*x*	*x*	*x*
9			855	105	960	*x*	*x*	*x*	*x*
10	York, *Cumberland*		310	40	350	*x*	*x*	*x*	*x*
11	Casey, *Clark*	28	1,925	55	1,980	*x*	*x*	*x*	*x*
12			190	15	205	*x*	*x*	*x*	*x*
13			400	0	400	*x*	*x*	*x*	*x*
14			1,525	15	1,540	*x*	*x*	*x*	*x*
15	Martinsville, *Clark*	27	710	155	865	*x*	*x*	*x*	*x*
16			15	20	35	*x*	*x*	*x*	*x*
17			275	35	310	*x*	*x*	*x*	*x*
18			105	0	105	*x*	*x*	*x*	*x*
19			170	0	170	*x*	*x*	*x*	*x*
20			195	0	195	*x*	*x*	*x*	*x*
21			5	0	5	*x*	*x*	*x*	*x*
22	North Johnson, *Clark*	27	1,320	20	1,340	*x*	*x*	*x*	*x*
23			1,115	0	1,115	*x*	*x*	*x*	*x*
24			160	0	160	*x*	*x*	*x*	*x*
25			820	5	825	*x*	*x*	*x*	*x*
26			215	0	215	*x*	*x*	*x*	*x*
27	South Johnson, *Clark*	27	1,715	65	1,780	*x*	*x*	*x*	*x*
28			185	5	190	*x*	*x*	*x*	*x*
29			295	0	295	*x*	*x*	*x*	*x*
30			1,675	35	1,710	*x*	*x*	*x*	*x*
31			845	5	850	*x*	*x*	*x*	*x*
32	Bellair, *Crawford, Jasper*	27	1,300	5	1,305	*x*	*x*	*x*	*x*
33			1,165	0	1,165	*x*	*x*	*x*	*x*
34			315	0	315	*x*	*x*	*x*	*x*
35			910	0	910	*x*	*x*	*x*	*x*
36	Clark County Division[1]		19,960	465	20,425	50,507,000±	475,000±	507,000	1,073
37	Main[2], *Crawford*	28	35,130	510	35,640	*x*	*x*	*x*	*x*
38			340	0	340	*x*	*x*	*x*	*x*
39			33,795	510	34,300	*x*	*x*	*x*	*x*
40			1,000	0	1,000	*x*	*x*	*x*	*x*
41	New Hebron, *Crawford*	25	1,350	210	1,460	*x*	*x*	*x*	*x*
42	Chapman, *Crawford*	20	1,045	515	1,560	*x*	*x*	*x*	*x*
43	Parker, *Crawford*	27	1,310	30	1,340	*x*	*x*	*x*	*x*
44	Allison-Weger, *Crawford*	*y*	1,075	20	1,095	*x*	*x*	*x*	*x*
45	Flat Rock[3], *Crawford*	*y*	1,375	545	1,820	*x*	*x*	*x*	*x*
46	Birds, *Crawford, Lawrence*	*y*	4,370	115	4,485	*x*	*x*	*x*	*x*
47	Crawford County Division[4]	28	45,655	1,945	47,600	137,311,000	1,471,000	1,572,000	3,500
48	Lawrence, *Lawrence, Crawford*	28	24,150	1,550	25,700	*x*	*x*	*x*	*x*
49			5,015	35	5,050	*x*	*x*	*x*	*x*
50			2,240	0	2,240	*x*	*x*	*x*	*x*
51			345	1,095	1,440	*x*	*x*	*x*	*x*
52			15,960	220	16,180	*x*	*x*	*x*	*x*
53			4,020	200	4,220	*x*	*x*	*x*	*x*
54			6,950	0	6,950	*x*	*x*	*x*	*x*
55	St. Francisville, *Lawrence*	*y*	420	0	420	*x*	*x*	*x*	*x*
56	Lawrence County Division[5]		24,570	1,550	26,120	215,650,000	1,650,000	1,908,000	4,300

[1] Total of lines 1, 2, 6, 10, 11, 15, 22, 27, 32.
[2] Includes Kibbie, Oblong, Robinson, and Hardinsville.
[3] Includes Swearingen Gas.
[4] Total of lines 37, 41, 42, 43, 44, 45, 46.
[5] Total of lines 48 and 55.

The best of the new producers were two wells in the Dupo field, St. Clair County, one of which had an initial production during the first 24 hr. of 257 bbl. and the other 92 bbl. Because of these two wells the average initial production per well in Illinois increased greatly, being 35 bbl. in 1934 as compared with 5.3 in 1933.

A sharp drop in production of the Dupo field in 1934 (total 40,200 bbl. as compared with 150,000 bbl. in 1933) resulted when some of the best producers in the field suddenly fell off in oil production and went almost entirely to water. It was then found that lifting costs for the field were greater than receipts for oil produced and it became necessary to increase production by drilling new wells. About 50 undrilled inside locations remain in the field, and further drilling is planned as new production is needed to fill market requirements.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age in Years to End of 1934	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil + Oil and Gas	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934
57	Allendale, *Wabash*	22	1,670	0	1,670	3,720,000±	220,000±	220,000±	600±
58	Southeastern Illinois Field[6]		91,855	3,960	95,815	407,188,000	3,816,000	4,207,000	9,473
59	Colmar-Plymouth, *McDonough, Hancock*	20.5	2,450	0	2,450	1,900,000	93,900	81,000	235
60	Pike County Gas, *Pike*	29 Abd. 1920±	0	8,960	8,960	0	0	0	0
61	Jacksonville Gas, *Morgan*	24	30	1,290	1,320	2,100	0	0	0
62	Carlinville, *Macoupin*	25 Abd. 1925±	30	50	80	*x*	0	0	0
63	Spanish Needle Creek, *Macoupin*	19	0	80	80	0	0	0	0
64	Gillespie (Wyen), *Macoupin*	19	40	0	40	*x*	1,095±	1,095±	3±
65	Gillespie-Benld Gas, *Macoupin*	11	0	80	80	0	0	0	0
66	Staunton, *Macoupin*	18 Abd. 1919	0	400	400	0	0	0	0
67	Litchfield, *Montgomery*	55 Abd. 1904	100	0	100	22,000	0	0	0
68	Collinsville, *Madison*	25 Abd. 1921	40	0	40	715	0	0	0
69	Ayers Gas, *Bond*	12	0	280	280	0	0	0	0
70	Greenville Gas, *Bond*	24 Abd. 1923	0	160	160	0	0	0	0
71	Carlyle, *Clinton*	23	915	0	915	3,226,000±	22,427	26,400	75
72	Frogtown, *Clinton*	16	300	0	300	*x*	0	0	0
73	Sandoval, *Marion*	25	770	0	770	2,550,000±	34,800	34,300	94
74	Centralia, *Marion*	24	175	0	175	*x*	*y*	*y*	*y*
75	Wamac, *Marion, Clinton, Washington*	13	250	0	250	300,000±	*x*	25,000±	68±
76	Dupo, *St. Clair*	6	670	0	670	773,000	150,000	40,200	93
77	Waterloo, *Monroe*	14 Abd. 1930	125	0	125	166,000	0	0	0
78	Sparta Gas, *Randolph*	46 Abd. *x*	65	100	165	*x*	0	0	0
79	Ava-Campbell Hill, *Jackson*	17	70	370	440	25,000	0	0	0
80	Total, Illinois[7]		97,885	15,730	113,615	416,728,000[8]	4,244,000	4,452,000	10,200

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[6] Total of lines 36, 47, 56, and 57.

[7] Total of lines 58 to 79, inclusive.

[8] The total oil production is the figure furnished by the U. S. Bureau of Mines and is not the exact total of the figures given in the table which were obtained from other sources.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1934		At End of 1934				
	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only or Oil and Gas	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	260	x	0.2	0	0	0	0	22	0	0	0	12	0	0	12
2	x	x	x	x	0	0	0	1,610	3	30	y	385	0	0	385
3	x	x	x	x	0	0	0	184	0	y	y	y	0	0	y
4	x	x	x	x	0	0	0	1,431	3	y	y	y	0	0	y
5	x	x	x	x	0	0	0	12	0	y	y	y	0	0	y
6	x	x	x	x	0	0	0	995	0	0	y	919	y	0	919
7	x	x	x	x	0	0	0	854	0	0	y	y	y	0	y
8	x	x	x	x	0	0	0	90	0	0	y	y	y	0	y
9	x	x	x	x	0	0	0	192	0	0	y	y	y	0	y
10	x	x	x	x	0	0	0	70	0	0	y	44	y	0	44
11	x	x	x	x	0	0	0	532	2	0	y	514	0	0	514
12	x	x	x	x	0	0	0	41	0	0	y	y	0	0	y
13	x	x	x	x	0	0	0	82	2	0	y	y	0	0	y
14	x	x	x	x	0	0	0	319	0	0	y	y	0	0	y
15	x	x	x	x	0	0	0	212	0	4	y	167	0	0	167
16	x	x	x	x	0	0	0	7	0	y	y	y	0	0	y
17	x	x	x	x	0	0	0	62	0	y	y	y	0	0	y
18	x	x	x	x	0	0	0	21	0	y	y	y	0	0	y
19	x	x	x	x	0	0	0	34	0	y	y	y	0	0	y
20	x	x	x	x	0	0	0	39	0	y	y	y	0	0	y
21	x	x	x	0	0	0	0	1	0	0	0	1	0	0	1
22	x	x	x	x	x	x	x	484	0	2	y	428	y	0	428
23	x	x	x	x	x	x	x	296	0	y	y	y	y	0	y
24	x	x	x	x	x	x	x	32	0	y	y	y	y	0	y
25	x	x	x	x	x	x	x	177	0	y	y	y	y	0	y
26	x	x	x	x	x	x	x	43	0	y	y	y	y	0	y
27	x	x	x	x	x	x	x	533	0	6	y	499	y	0	499
28	x	x	x	x	x	x	x	38	0	y	y	y	y	0	y
29	x	x	x	x	x	x	x	59	0	y	y	y	y	0	y
30	x	x	x	x	x	x	x	401	0	y	y	y	y	0	y
31	x	x	x	x	x	x	x	170	0	y	y	y	y	0	y
32	x	x	x	x	x	x	x	485	0	0	y	409	0	0	409
33	x	x	x	x	x	x	x	309	0	0	y	y	0	0	y
34	x	x	x	x	x	x	x	63	0	0	y	y	0	0	y
35	x	x	x	x	x	x	x	182	0	0	y	y	0	0	y
36	2,530	80±	0.3	x	y	y	y	4,943	5	42	13	3,334	y	0	3,334
37	x	x	x	x	x	x	x	7,310	1	146	y	5,506	y	0	5,506
38	x	x	x	x	x	x	x	68	0	y	y	y	0	0	y
39	x	x	x	x	x	x	x	7,132	1	y	y	y	y	0	y
40	x	x	x	x	x	x	x	108	0	y	y	y	y	0	y
41	x	x	x	x	x	x	x	295	0	5	y	198	0	0	198
42	x	x	x	x	x	x	x	193	0	3	y	91	0	0	91
43	x	x	x	x	x	x	x	255	0	5	y	221	0	0	221
44	x	x	x	x	x	x	x	146	0	5	y	72	0	0	72
45	x	x	x	x	x	x	x	280	0	1	y	163	0	0	163
46	x	x	x	x	x	x	x	682	0	9	y	477	0	0	477
47	3,000	120±	0.5	x	y	y	y	9,161	1	174	32	6,696	y	0	6,696
48	x	x	x	x	x	x	x	4,381	0	67	5	3,366	y	y	3,366
49	x	x	x	x	x	x	x	1,228	0	y	y	y	y	y	y
50	x	x	x	x	x	x	x	473	0	y	y	y	y	y	y
51	x	x	x	x	x	x	x	243	0	y	y	y	y	y	y
52	x	x	x	x	x	x	x	3,017	0	y	y	y	y	y	y
53	x	x	x	x	x	x	x	684	0	y	y	y	y	y	y
54	x	x	x	x	x	x	x	950	0	y	y	y	y	y	y
55	x	x	x	x	x	x	x	54	0	0	y	45	y	y	45
56	8,800	160±	1.0	x	y	y	y	4,435	0	67	5	3,411	y	y	3,411
57	2,230	112±	1.5	x	y	y	y	407	2	6	0	341	y	0	341
58	4,430	130±	0.7	x	y	y	y	18,946	8	289	50	13,782	y	0	13,782
59	770	37	0.8	0	0	0	0	450	0	0	32	281	0	0	281
60	0	0	0	x	0	0	0	68	0	0	0	0	0	0	0

[b] Footnotes to column headings and explanation of symbols are on page 249.

The two wells in Wabash County that opened a new pool 1½ miles south of the nearest production had initial productions of 12 bbl. (after shot) and 2 bbl. (natural), respectively. The productive area is bounded by dry holes one location to the northwest and southwest but it may extend eastward. Experience has shown that the production in Wabash County is very spotty, so the new pool probably will not be large. The producing horizon is the Biehl sand near the base of the Pennsylvanian system.

Nine of the 14 dry holes were drilled without reference to geological conditions and in areas where detailed structure is not known. Of the remaining five, one was in the old Sparta gas field, Randolph County; one on the Martinsville dome in Clark County between the Martinsville and North Johnson pools; one in northern Crawford County, where many dry patches are interspersed in the producing territory; one was an offset to one of the new wells in Wabash County mentioned above and one was on the Stubblefield anticline, Bond County, but not on structural closure.

Through the cooperation of the oil companies excellent information is being obtained from the new drilling. Sample cuttings saved at frequent regular intervals were obtained from 22 of the 26 new wells and from two wells that were deepened. The cuttings are studied in the subsurface laboratory of the State Geological Survey, where they

TABLE 1.—(*Continued*)

	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1934		At End of 1934				
Line Number	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only or Oil and Gas	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
61	70	14±	0	x	0	0	0	53	0	y	y	0	0	y	y
62	x	x	0	x	0	0	0	8	0	0	0	0	0	0	0
63	0	0	0	14.44	0±	0	0	7	0	0	7	0	0	0	0
64	x	x	0.75±	0	0	0	0	11	0	0	0	4	0	0	4
65	0	0	0	135.8	6.53	0	0	4	0	0	4	0	0	0	0
66	0	0	0	1,050	0	0	0	18	0	0	0	0	0	0	0
67	220	x	0	x	0	0	0	17	0	0	0	0	0	0	0
68	x	x	0	0	0	0	0	5	0	0	0	0	0	0	0
69	0	0	0	67	13.4	13.45	x	10	0	0	0	0	0	7	7
70	0	0	0	990	0	0	0	4	0	0	0	0	0	0	0
71	3,500±	175±	0.8	0	0	0	0	164	0	0	6	92	0	0	92
72	x	x	0	0	0	0	0	12	0	0	0	0	0	0	0
73	3,250±	162±	2.8	0	0	0	0	122	0	10	9	34	0	0	34
74	x	x	y	0	0	0	0	22	0	y	y	y	0	0	y
75	1,200±	60±	1.5	0	0	0	0	103	0	11	0	45	0	0	45
76	1,150	23	2.2	0	0	0	0	227	2	9	6	42	0	0	42
77	1,328	y	0	0	0	0	0	23	0	0	0	0	0	0	0
78	x	x	0	x	0	0	0	20	0	0	0	0	0	0	0
79	35	x	0	x	0	0	0	35	0	0	0	0	0	0	0
80	4,260		0.72	x	y	y	y	20,329	10	319	107	14,280	y	7	14,287

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1934		Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1934					Character of Gas Approx. Average during 1934	
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells, Pumping	Injection into Reservoir[d]	Initial	Average at End of 1933	Average at End of 1934	Gravity[l] A. P. I. at 60° F. Maximum	Gravity[l] A. P. I. at 60° F. Minimum	Gravity[l] A. P. I. at 60° F. Weighted Average	Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
1	215	159	12		*x*	*x*	*x*	*x*	*x*	*x*	*y*	*y*		
2			385		200±	*x*	*x*	38.4	28.3	34.0	*y*	M	*x*	*x*
3	376	281	*y*		*x*	*x*	*x*	*y*	*y*	30.0	*y*	M	*x*	*x*
4	446	334	*y*		*x*	*x*	*x*	*y*	*y*	33.5	*y*	M	*x*	*x*
5	2,568	2,265	*y*		*x*	*x*	*x*	*y*	*y*	37.0	*y*	M	*x*	*x*
6			919	A2	*x*	*x*	*x*	36.9	27.4	33.0	*y*	M	*x*	*x*
7	465	367	*y*		*x*	*x*	*x*	*y*	*y*	(34.0)	*y*	M	*x*	*x*
8	562	478	*y*		*x*	*x*	*x*	*y*	*y*	(33.6)	*y*	M	*x*	*x*
9	590	556	*y*		*x*	*x*	*x*	*y*	*y*	(25.7)	*y*	M	*x*	*x*
10	680	588	44		*x*	*x*	*x*	33.9	30.0	(30.3)	*y*	M	*x*	*x*
11			514	[9]	*x*	*x*	*x*	37.2	27.2	29.2	*y*	M	*x*	*x*
12	358	263	*y*		*x*	*x*	*x*	*y*	*y*	(31.9)	*y*	M	*x*	*x*
13	426	309	*y*		*x*	*x*	*x*	*y*	*y*	(30.1)	*y*	M	*x*	*x*
14	505	444	*y*		*x*	*x*	*x*	*y*	*y*	(33.6)	*y*	M	*x*	*x*
15			167	A2	*x*	*x*	*x*	37.5	30.2	36.8	*y*	M	*x*	*x*
16	411	255	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
17	511	449	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
18	506	477	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
19	1,418	1,340	*y*		*x*	*x*	*x*	*y*	*y*	(38.9)	*y*	M	*x*	*x*
20	1,596	1,553	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
21	2,830	2,708	1		*x*	*x*	*x*	*y*	*y*	(39.6)	*y*	M	*x*	*x*
22			428		*x*	*x*	*x*	36.2	27.7	31.0	*y*	M	*x*	*x*
23	486	416	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
24	451	314	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
25	508	465	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
26	554	534	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
27			499		*x*	*x*	*x*	35.1	28.5	32.2	*y*	M	*x*	*x*
28	549	392	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
29	518	453	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
30	570	489	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
31	618	598	*y*		*x*	*x*	*x*	*y*	*y*	(28.5)	*y*	M	*x*	*x*
32			409	AG2	*x*	*x*	*x*	35.6	27.3	33.7	*y*	M	*x*	*x*
33	726	561	*y*		*x*	*x*	*x*	*y*	*y*	(32.4)	*y*	M	*x*	*x*
34	907	817	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
35	920	886	*y*		*x*	*x*	*x*	*y*	*y*	(37.0)	*y*	M	*x*	*x*
36			3,334	G1 A7 AG13	*x*	*x*	*x*	39.6	25.8	33.0	*y*		*x*	*x*
37			5,506	[10]	425±	*y*	*y*	38.6	25.1	33.0	0.23	M	960	2.5
38	822	508	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
39	960	900	*y*	[11]	425±	*x*	*x*	36.8	25.1	32.8	*y*	M	960	2.5
40	1,416	1,337	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
41	975	940	198	G2	*x*	*x*	*x*	35.0	24.3	30.1	*y*	*y*	*x*	*x*
42	1,015	995	91	AG1	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
43	1,025	1,000	221		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
44	930	912	72		*x*	*x*	*x*	30.4	22.6	29.5	*y*	*y*	*x*	*x*
45	945	935	163		*x*	*x*	*x*	26.6	18.5	22.5	*y*	*y*	*x*	*x*
46	950	930	477	A7	*x*	*x*	*x*	34.1	20.0	31.3	*y*	*y*	*x*	*x*
47			6,696	[12]	425±	*x*	*x*	38.6	18.5	32.5	*y*	M	960	2.5

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[d] A special definition of *d* for application to this table follows: W, water; G, gas; A, air; AG, air-gas mixture. Numbers in this column indicate numbers of injection wells.

[l] A special definition of *l* for application to this table follows: All gravities given (except those in parentheses) were from data for the year 1925 furnished by the Illinois Pipe Line Co. Gravities in parentheses are for particular samples; see Illinois State Geol. Survey *Bull.* 54, Table 3. The values have been converted from Baumé to A.P.I. gravities.

[9] G1, A3, AG11.

[10] G15, A24, AG20, W1.

[11] G15, A24, AG20, W1.

[12] G17, A31, AG21, W1.

are preserved for comparison with other well cuttings, and reports on the cuttings received are furnished to the well owner. The Survey's Baker cable-tool core barrel[1] was used twice during 1934 to obtain cores of producing formations in Illinois fields. One core was obtained in the Colmar-Plymouth field and the other in the Dupo field, both in western Illinois. The thicknesses of strata cored were 24½ and 45 ft. respectively. Tests in the Survey laboratories for porosity, saturation and permeability

TABLE 1.—(*Continued*)

	Average Depth, Ft.		Oil Production Methods at End of 1934		Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1934					Character of Gas Approx. Average during 1934	
						Average at End of		Gravity[l] A. P. I. at 60° F.						
Line Number	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells, Pumping	Injection into Reservoir[d]	Initial	1933	1934	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
48			3,366	A1	650±	*x*	*x*	39.3	26.7	32.9		M	*x*	2.4
49	1,000	800	*y*		*x*	*x*	*x*	*y*	*y*	*y*	0.27	*y*	*x*	*x*
50	1,265	1,250	*y*		*x*	*x*	*x*	*y*	*y*	*y*	0.24	*y*	*x*	*x*
51	1,345	1,330	*y*		*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*	*x*	*x*
52	1,430	1,400	*y*		600	*x*	*x*	*y*	*y*	*y*	0.20	*y*	*x*	*x*
53	1,580	1,560	*y*		650	*x*	*x*	*y*	*y*	*y*	0.17	*y*	*x*	*x*
54	1,710	1,700	*y*		*x*	*x*	*x*	*y*	*y*	*y*	0.35	*y*	*x*	*x*
55	1,865	1,843	45		600	*x*	*x*	37.3	37.3	37.3	*y*	*y*	*x*	*x*
56			3,411	A1		*x*	*x*						*x*	
57	1,460	1,425	341	G1	*x*	*x*	*x*	35.9	24.1	35.1	0.25	*y*	*x*	*x*
58			13,782	G19 A38 AG34 W1				39.3	18.5	33.1			*y*	2.4
59	468	447	281	A9	*x*	*x*	*x*	*y*	*y*	37.5	*y*	*y*		
60	275	265	0		*x*	*x*	*x*						*x*	*x*
61	330	335	0		*x*	*x*	*x*	*x*	*x*	*x*	*x*	*y*	898	0.05
62	398	380	0		135	*x*	*x*	*x*	*x*	27.7±	*x*	*y*	*x*	*x*
63	405	385	0		*x*	*x*	*x*						*y*	*y*
64	670	650	4		*x*	*x*	*x*	*y*	*y*	29.2	*x*	*y*		
65	555	542	0		155	*x*	*x*						788	*y*
66	491	461	0		145	*x*	*x*						*x*	*x*
67	674	644	0		*x*	*x*	*x*	*x*	*x*	21.7	*x*	*y*	*x*	*x*
68	1,400	1,305	0		*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
69	945	940	0		345	*x*	315±						*y*	*y*
70	993	927	0		*x*	*x*	*x*						1,050	0
71	1,055	1,035	92	W3	*x*	*x*	*x*	37.0	34.2	35.2	*y*	*y*	*x*	*x*
72	957	950	0		*x*	*x*	*x*	*y*	*y*	31.9	*y*	*y*	*x*	*x*
73	1,560	1,540	34		*x*	*x*	*x*	35.1	32.7	34.5	*y*	*y*		
74	1,150	1,130	*y*		*x*	*x*	*x*	35.0	31.0	32.3	*y*	*y*		
75	760	720	45	W5	*x*	*x*	*x*	30.8	29.3	30.2	*y*	P		
76	601	651	42		*x*	*x*	*x*	*y*	*y*	32.7	*y*	*y*		
77	460	410	0		*x*	*x*	*x*	30.1	29.5	30.0	*x*	*x*		
78	857	850	0		*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
79	798	780	0		115	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
80			14,280	G19 A38 AG34 W9										

[d] A special definition of *d* for application to this table follows: W, water; G, gas; A, air; AG, air-gas mixture. Number in this column indicate numbers of injection wells.

[l] A special definition of *l* for application to this table follows: All gravities given (except those in parentheses) were from data for the year 1925 furnished by the Illinois Pipe Line Co. Gravities in parentheses are for particular samples; see Illinois State Geol. Survey *Bull.* 54, Table 3. The values have been converted from Baumé to A.P.I. gravities.

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[1] For a discussion of the use of the core barrel see: A. H. Bell and R. J. Piersol: The Need for Sand Coring in the Southeastern Illinois Oil Field. Ill. State Geol. Survey, Illinois Petroleum No. 21 (Dec. 19, 1931).

TABLE 1.—(*Continued*)

Line Number	Producing Rock					Structure[j]	Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.			Name	Depth of Hole, Ft.
1	Unnamed	Pen	S	Por	*x*	ML	0	Pen	715
2	See below.					D	99	Trenton (Ord)	2,918
3	Shallow gas sand	Pen	S	Por	36	D	*x*		
4	Westfield lime	MisL	L	Por Cav	*x*	D	*x*		
5	Trenton	Ord	L	Por	*x*	D	*x*		
6	See below.					D	28	Dev limestone	2,010
7	First Siggins sand	Pen	S	Por	*x*	D	*x*		
8	Second and Third Siggins sand	Pen	S	Por	*x*	D	*x*		
9	Lower Siggins sand	Pen	S	Por	*x*	D	*x*		
10	York sand	Pen	S	Por	*x*	AM	2		960
11	See below.					AM	20	MisL	808
12	Upper gas sand	Pen	S	Por	*x*	AM	5		
13	Lower gas sand	Pen	S	Por	*x*	AM	12		
14	Casey sand	Pen	S	Por	*x*	AM	20		
15	See below.					D	5	St. Peter	3,411
16	Shallow sands	Pen	S	Por	*x*	D	1		
17	Casey sand	Pen	S	Por	*x*	D	5		
18	Martinsville sand	MisL	L	Por	*x*	D	1		
19	Carper	MisL	S	Por	*x*	D	1		
20	"Niagaran"	Dev	L	Por	*x*	D	3		
21	Trenton	Ord	L	Por	*x*	D	1		
22	See below.					AM	16	Mis	965
23	Claypool sand	Pen	S	Por	*x*	AM	12		
24	Shallow sands	Pen	S	Por	*x*	AM	4		
25	Casey sand	Pen	S	Por	*x*	AM	12		
26	Upper Partlow	Pen	S	Por	*x*	AM	16		
27	See below.					AM	29	Mis	1,160
28	Claypool sand	Pen	S	Por	*x*	AM	3		
29	Casey sand	Pen	S	Por	*x*	AM	11		
30	Upper Partlow	Pen	S	Por	*x*	AM	29		
31	Lower Partlow	Pen	S	Por	*x*	AM	10		
32	See below.					AM	14	MisL	1,471
33	"500-ft. sand"	Pen	S	Por	*x*	AM	3		
34	"800-ft. sand"	Pen	S	Por	*x*	AM	3		
35	"900-ft. sand"	MisU	S	Por	*x*	AM	12		
36					33±		213		
37	See below.						200±	Trenton (Ord)	4,620
38	Shallow sand	Pen	S	Por	*x*	ML	*x*		
39	Robinson sand	Pen	S	Por	25±	ML	167	Trenton (Ord)	4,620
40	Oblong	Mis	S or L	Por	*x*	A, ML	23	Mis	1,479
41	Robinson sand	Pen	S	Por	*x*	ML	5	MisL	2,056
42	Robinson sand	Pen	S	Por	*x*	ML	10	Mis	2,279
43	Robinson sand	Pen	S	Por	*x*	ML	10	Pen?	1,127
44	Robinson sand	Pen	S	Por	*x*	ML	6	Pen	1,041
45	Robinson (Flat Rock)	Pen	S	Por	*x*	ML	8	Pen	1,032
46	Robinson sand	Pen	S	Por	*x*	ML	12	MisL	1,731
47		Pen, Mis	S	Por	*x*	ML	251	Trenton (Ord)	4,620
48	See below.					A	83	St. Peter	5,190
49	Bridgeport sand	Pen	S	Por	40	A	19		
50	Buchanan	Pen	S	Por	15	A	3		
51	"Gas" sand	MisU	S	Por	15	A	5		
52	Kirkwood	MisU	S	Por	30	A	10		
53	Tracy	MisU	S	Por	10	A	11		
54	McClosky	MisL	L	Por	10	A	23		
55	Kirkwood	MisU	S	Por	22	ML	0	Mis	1,900
56							83	St. Peter	5,190
57	Biehl sand	Pen	S	Por	35±	AM	43	MisL	2,228
58							590		
59	Hoing sand	Dev	S	Por	21	A	0	Trenton (Ord)	805
60	Niagaran	Sil	L	Por	10	A	0	St. Peter	893
61	Gas sand	Pen Mis	S, H, SL	Por	5	ML	8	Trenton (Ord)	1,390

are now in progress and the results are to be published. It is planned that further coring of Illinois oil sands will be carried on as opportunity arises, in order to furnish data regarding Illinois oil sands that are needed in the application of improved recovery methods.

The second annual petroleum conference of Illinois, sponsored by the Illinois-Indiana Petroleum Association and the Illinois State Geological Survey, was held June 1, 1934, at Robinson. About 125 oil men attended. Among the subjects discussed at the conference were air repressuring, water-flooding, acid treatment of wells, treatment of crude oil emulsions, exploration for new fields, and the research needs of the Illinois-Indiana petroleum industry[2].

The air-repressuring project of the Ohio Oil Co. in the Plymouth field, McDonough County, mentioned in last year's report, began operation Feb. 10, 1934. Monthly production of one lease in this pool was increased from about 800 bbl. per month to about 1300 bbl. by repressuring. The gain in production in the leases affected, however, was not sufficient to offset losses in other parts of the field (Table 1). A considerable extension of repressuring in the Colmar-Plymouth field is planned and new machinery is being installed. This was the only new repressuring operation in Illinois during 1934. All repressuring plants previously in operation were continued during the year.

TABLE 1.—(*Continued*)

Line Number	Producing Rock					Structure[j]	Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.			Name	Depth of Hole, Ft.
62	Unnamed	Pen	S	Por	*x*	A	0	Pen	410
63	Unnamed	Pen	S	Por	*x*	D	1	Pen	495
64	Unnamed	Pen	S	Por	*x*	T	9	Trenton (Ord)	2,560
65	Unnamed	Pen	S	Por	*x*	A	0	Pen	575
66	Unnamed	Pen	S	Por	*x*	A	0	Trenton (Ord)	2,371
67	Unnamed	Pen	S	Por	*x*	D	0	Pen	681
68	Trenton	Ord	L	Por	20	ML	0	Trenton (Ord)	1,500
69	Lindley	MisU	S	Por	5	A	0	MisL	1,150
70	Lindley	MisU	S	Por	*x*	A	0	Mis	1,065
71	Carlyle	MisU	S	Por	20	A	17	Sil	2,620
72	Carlyle	MisU	S	Por	7	D	0	Carlyle *y*	962±
73	Benoist	MisU	S	Por	20±	D	7	Mis	1,732
74	Dykstra, Wilson, Benoist	MisU	S	Por	20	D, ML	6	MisL	1,779
75	Petro	Pen	S	Por	20	D	0	Benoist	1,484
76	Trenton	Ord	L	Por Cav	50	A	0	Trenton	819
77	Trenton	Ord	L	Por	50	A	19	Trenton	845
78	Sparta gas sand	MisU	S	Por	7	D	5	MisU	985
79	Unnamed	MisU	S	Por	18	A	*y*	Dev	2,530
80							661±		

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[2] Papers on Improved Methods of Exploring for and Recovering Petroleum in Illinois. Ill. State Geol. Survey and Ill.-Ind. Petr. Assn. (December, 1934). Available on request to the Chief, Illinois State Geological Survey, Urbana.

TABLE 2.—*Summary of Drilling Operations in Illinois*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to January 1, 1935									Completed during 1934				Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes								Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes			Productive Wells (For Details, See Table 1)		
	Total Depths, Ft.							Total		Total Depths, Ft.		Total		Within Fields	Exploratory
	Less than 1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	Unknown			Less than 1,000	1,000–2,000				
Adams	0	8	1	0	0	0	0	9	0	0	0	0	0	0	0
Alexander	0	3	0	0	0	0	0	3	0	0	0	0	0	0	0
Bond	5	29	8	0	0	0	0	42	14	0	2	2	0	0	0
Boone	0	2	1	0	0	0	0	3	0	0	0	0	0	0	0
Brown	5	1	0	0	0	0	0	6	0	0	0	0	0	0	0
Bureau	0	8	2	0	0	0	0	10	0	0	0	0	0	0	0
Calhoun	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Carroll	0	2	1	0	0	0	0	3	0	0	0	0	0	0	0
Cass	0	3	0	0	0	0	0	3	0	0	0	0	0	0	0
Champaign	3	11	0	0	0	0	0	14	0	0	0	0	0	0	0
Christian	1	6	1	0	0	0	0	8	0	0	0	0	0	0	0
Clark	334	13	9	1	0	0	507	864	3,335	2	0	2	5	1	1
Clay	0	3	6	0	0	0	0	9	0	0	0	0	0	0	0
Clinton	6	84	3	0	0	0	2	95	180	0	1	1	0	0	0
Coles	20	9	6	0	0	0	4	39	127	0	0	0	0	0	0
Cook	0	183	34	0	0	0	0	217	0	0	0	0	0	0	0
Crawford	213	261	3	0	1	0	914	1,392	9,545	1	0	1	1	0	2
Cumberland	69	8	4	0	0	0	27	108	974	1	0	1	0	0	0
De Kalb	0	8	1	0	0	0	0	9	0	0	0	0	0	0	2
De Witt	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Douglas	11	7	1	0	0	0	0	19	0	0	0	0	0	0	1
Du Page	0	7	14	0	0	0	0	21	0	0	0	0	0	0	0
Edgar	8	6	4	0	0	0	0	18	22	0	0	0	0	0	0
Edwards	0	7	3	0	0	0	0	10	0	0	0	0	0	0	1
Effingham	1	5	1	0	0	0	0	7	0	0	0	0	0	0	0
Fayette	0	9	3	0	0	0	0	12	0	0	1	1	0	0	0
Franklin	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Fulton	2	11	3	0	0	0	0	16	0	0	0	0	0	0	0
Gallatin	1	14	1	2	0	0	0	18	0	0	0	0	0	0	0
Greene	0	5	0	0	0	0	0	5	0	0	0	0	0	0	2
Grundy	0	4	1	0	0	0	0	5	0	0	0	0	0	0	0
Hamilton	0	2	1	0	0	0	0	3	0	0	0	0	0	0	0
Hancock	0	3	0	0	0	0	0	3	17	0	0	0	0	0	0
Hardin	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Henderson	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0
Henry	2	17	3	0	0	0	0	22	0	0	0	0	0	0	0
Iroquois	2	4	0	0	0	0	0	6	0	0	0	0	0	0	0
Jackson	22	32	2	0	0	0	0	56	35	0	0	0	0	0	0
Jasper	4	11	2	0	0	0	0	17	17	0	0	0	0	0	1
Jefferson	0	8	5	0	0	0	0	13	0	0	1	1	0	0	0
Jersey	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0
Jo Daviess	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0
Johnson	0	3	2	0	0	0	0	5	0	0	0	0	0	0	0
Kane	0	10	11	0	0	0	0	21	0	0	0	0	0	0	0
Kankakee	1	4	0	0	0	1	0	6	0	0	0	0	0	0	0
Kendall	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Knox	1	10	3	0	0	0	0	14	0	0	0	0	0	0	0
Lake	0	27	7	0	0	0	0	34	0	0	0	0	0	0	0
La Salle	0	19	7	0	0	0	0	26	0	0	0	0	0	0	0
Lawrence	83	301	69	0	0	1	56	510	4,519	0	0	0	0	0	0

TABLE 2.—(*Continued*)

County	Completed Prior to January 1, 1935									Completed during 1934				Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes								Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes			Productive Wells (For Details, See Table 1)		
	Total Depths, Ft.							Total		Total Depths, Ft.		Total			
	Less than 1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	Unknown			Less than 1,000	1,000–2,000			Within Fields	Exploratory
Lee	0	9	1	0	0	0	0	10	0	0	0	0	0	0	0
Livingston	0	10	3	0	0	0	0	13	0	0	0	0	0	0	0
McDonough	1	5	1	0	0	0	0	7	433	1	0	1	0	0	0
McHenry	0	3	3	0	0	0	0	6	0	0	0	0	0	0	0
McLean	0	3	2	0	0	0	0	5	0	0	0	0	0	0	0
Macon	0	6	7	0	0	0	0	13	0	0	0	0	0	0	0
Macoupin	24	0	4	0	0	0	0	28	48	0	0	0	0	0	1
Madison	2	13	0	4	0	0	0	19	5	0	0	0	0	0	1
Marion	3	28	4	0	0	0	0	35	240	0	0	0	0	0	1
Marshall	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0
Mason	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0
Massac	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Mercer	0	4	0	2	0	0	0	6	0	0	0	0	0	0	0
Monroe	20	2	1	0	0	0	0	23	23	1	0	1	0	0	1
Montgomery	5	7	2	1	0	0	0	15	17	0	0	0	0	0	0
Morgan	22	6	0	1	0	0	0	29	53	1	0	1	0	0	0
Moultrie	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Ogle	0	4	2	0	0	0	0	6	0	0	0	0	0	0	0
Peoria	0	8	0	0	0	0	0	8	0	0	0	0	0	0	0
Perry	0	21	0	2	0	0	0	23	0	0	1	1	0	0	0
Piatt	0	4	1	0	0	0	0	5	0	0	0	0	0	0	0
Pike	12	0	0	0	0	0	0	12	68	0	0	0	0	0	0
Pope	1	2	0	2	0	0	0	5	0	0	0	0	0	0	0
Pulaski	0	2	1	0	0	0	0	3	0	0	0	0	0	0	0
Putnam	0	4	0	0	0	0	0	4	0	0	0	0	0	0	0
Randolph	11	12	0	0	0	0	0	23	20	1	0	1	0	0	0
Richland	4	2	0	0	0	0	0	6	0	0	0	0	0	0	0
Rock Island	1	10	4	0	0	0	0	15	0	0	0	0	0	0	1
St. Clair	16	3	0	0	0	0	0	19	227	1	0	1	2	0	0
Saline	0	19	6	1	0	0	0	26	0	0	0	0	0	0	0
Sangamon	1	2	2	0	0	0	0	5	0	0	0	0	0	0	0
Schuyler	23	10	0	0	0	0	0	33	0	0	0	0	0	0	0
Scott	2	1	0	0	0	0	0	3	0	0	0	0	0	0	0
Shelby	0	11	0	0	0	0	0	11	0	0	0	0	0	0	0
Stark	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0
Stephenson	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0
Tazewell	0	2	2	0	0	0	0	4	0	0	0	0	0	0	0
Union	0	3	4	0	0	0	0	7	0	0	0	0	0	0	0
Vermilion	2	10	0	0	0	0	0	12	0	0	0	0	0	0	0
Wabash	2	168	10	0	0	0	145	325	407	0	1	1	2	0	0
Warren	0	2	2	0	0	0	0	4	0	0	0	0	0	0	0
Washington	4	14	0	0	0	0	0	18	3	0	0	0	0	0	0
Wayne	0	5	0	0	0	0	0	5	0	0	0	0	0	0	0
White	0	4	2	0	0	0	0	6	0	0	0	0	0	0	0
Whiteside	0	6	0	0	0	0	0	6	0	0	0	0	0	0	0
Will	0	32	0	0	0	0	0	32	0	0	0	0	0	0	1
Williamson	0	6	0	0	0	0	0	6	0	0	0	0	0	0	0
Winnebago	0	15	1	0	0	0	0	16	0	0	0	0	0	0	0
Woodford	0	3	2	0	0	0	0	5	0	0	0	0	0	0	0
Total	950	1,665	294	16	1	2	1,655	4,583	20,329	9	7	16	10	1	17

No new water-flooding operations were begun in Illinois in 1934 but that begun in 1933 by the Tide Water Oil Co., on the Drake and Stifle leases, secs. 1 and 12, T.7N., R.13W., Crawford County, has had marked success to date. Water has been injected into one well since October, 1933, and three offset wells began to show increases in production before the beginning of 1934. The total increase in production due to flooding during 1934 was about 2000 bbl., which represents an increase in production of about 60 per cent for the two leases affected. This operation is reported to have been carried on at practically no additional operating expense.

The only other controlled water-flooding in Illinois is in the Carlyle field, Clinton County. Gains in production have been small but this is believed to be due to unfavorable sand conditions in the small part of the field that is now affected. The increase in production for the field from about 22,400 bbl. in 1933 to about 26,300 bbl. in 1934 is mainly due to reduction of artificial curtailment.

Large quantities of oil undoubtedly remain underground in Illinois fields. Using available data, this quantity is estimated at 1,600,000,000 bbl. Because natural gas pressure in the reservoirs is now practically exhausted, artificial restoration of pressure is necessary in order that substantial quantities of oil may be recovered in the future. In recent years economic conditions have retarded the adoption of new repressuring and water-flooding operations but doubtless these will be greatly extended when economic conditions are favorable.

Experiments with the acid treatment of wells producing from calcareous formations were begun in Illinois in the fall of 1933 and carried on during the first half of 1934. Of 11 wells treated with acid in 1934, eight yielded increased production. Seven of the latter were wells in the McClosky "sand" (Ste. Genevieve limestone, Lower Mississippian) and one was in the Kimmswick ("Trenton") limestone. The best increases were all in the McClosky wells in Lawrence County, several of which increased from 2 or 3 bbl. per day to 15 or 16 bbl. per day average for the first two weeks. Data are not available on the subsequent decline of these wells but in most cases the cost of the acid treatment is doubtless less than the increased returns from the oil produced. Acid treatment in wells in the Westfield lime (St. Louis and Salem limestones, Lower Mississippian) have all been failures. Two of the operations during 1934 were on new wells that did not produce, so that these failures cannot be counted as failures of acid treatment. Acid treatment in Illinois ceased about the middle of 1934, when curtailment of new production became necessary on account of lessened market demand. As about 1344 wells are producing from limestone in Illinois, opportunities exist for further use of acid treatment to stimulate production when market demand warrants.

Statistics of natural gas production in Illinois in 1934 are not yet available. Only one field, the Ayers, Bond County, is now producing gas for municipal supply (Table 1). Total production for the state, including gas used for power on oil leases, was 1,631,000,000 cu. ft. in 1933. The average value at the wells was 8 cents per thousand cubic feet.

A preliminary estimate of natural gasoline production in Illinois for 1934 is 3,789,000 gal.[3] Table 3 gives data concerning natural gasoline from 1929 to 1933 inclusive. On Jan. 1, 1934, there were 79 natural gasoline plants in Illinois, two of which were shut down[4]. All are of the compression type. One is in Wabash County, 26 in Lawrence County, 7 in Clark, and 43 in Crawford County.

TABLE 3.—*Natural Gasoline Produced in Illinois*

Year	Production, Thousands of Gallons	Value		Natural Gas Treated, Millions Cu. Ft.	Yield, Gal. per M. Cu. Ft.
		Total Thousands of Dollars	Unit Cents		
1929	7080	617	8.7	2760	2.57
1930	6840	420	6.1	2721	2.52
1931	5024	204	4.6	2106	2.39
1932	4558	139	3.2	1924	2.37
1933	3673	194	5.3	1701	2.14
PRODUCED BY COUNTIES IN 1932					
Counties					
Clark and Cumberland...	495	18		317	1.56
Crawford...............	1895	70		742	2.55
Lawrence...............	2168	51		865	2.51
State total.............	4558	139		1924	2.37

Production data for oil and gas were furnished by the U.S. Bureau of Mines; the Illinois Pipe Line Co., Findlay, Ohio; the Ohio Oil Co., Marshall, Ill.; Petro Oil and Gas Co., St. Louis, Mo.; Bond County Gas Co., Greenville, Ill.; and Illinois Power and Light Corporation, Hillsboro, Ill. Mr. P. S. McClure of the Illinois State Geological Survey assisted the writer in assembling the data. Messrs. Frederick Squires and Frank Marshall, both formerly of the Survey staff, assembled many data which are repeated in this year's report. Mr. Squires also obtained the data regarding the Tide Water Oil Company's water-flooding operation in Crawford County.

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[3] Communication from G. R. Hopkins, Acting Chief Economist, Petroleum Economics Division, U.S. Bureau of Mines, Feb. 5, 1935.

[4] G. R. Hopkins and E. M. Seeley: Natural-gasoline Plants in the United States, January 1, 1934. U.S. Bur. Mines *Inf. Circ.* 6808 (November, 1934).

Oil and Gas Developments in Indiana 1934

By W. N. Logan* and J. P. Kerr†

Lack of reliable and detailed information on many of the older fields in Indiana has necessitated the use of *x* and *y* in many instances. Even in the younger fields many data were lacking. It was thought that even though much was to be desired regarding the amount and accuracy of the information on the old Trenton field, it was too important to be left out. We trust that we are not perpetuating any of the inaccuracies that are to be found in the data for Indiana.

Table 1.—*Oil and Gas Production in Indiana*

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres			
			Oil	Oil and Gas[a]	Gas	Total
1	Trenton[1]	48	102,*xxx*	25,*xxx*	65*x*,*xxx*	778,*xxx*
2	Greensburg, *Decatur*	41	0	0	19,*xxx*	19,*xxx*
3	Peru, Erie, and Rich Valley[2], *Miami and Wabash*	37	1,6*xx*	0	0	1,6*xx*
4	Gifford[3], *Jasper*	36	5,*xxx*	0	0	5,*xxx*
5	Loogooree, *Daviess and Martin*	34	60	0	60	120
6	West Princeton, *Gibson*	31	860	0	0	860
7	Arthur (Oakland City), *Pike*	27	700	0	*y*	700
8	Harrison (Laconia), *Harrison*	24	0	0	6,200	6,200
9	Shelburn-Graysville[4], *Sullivan*	23	4,1*xx*	3*xx*	1,8*xx*	6,2*xx*
11	Union-Bowman[5], *Gibson-Pike*	18	2,4*xx*	0	4*xx*	2,8*xx*
12	Alford, *Pike*	15	220	0	870	1,090
13	Oatsville-Wheeling[5], *Pike-Gibson*	15	1,6*xx*	0	0	1,6*xx*
14	East Princeton, *Gibson*	14	*y*	*y*	*y*	*y*
15	Tri County, *Gibson-Pike*	9	160	0	0	160
16	Veale, *Daviess*	8	400	0	0	400
17	Siosi, *Vigo-Sullivan*	8	510	0	0	510
18	Rock Hill, *Spencer*	6	60	0	0	60
19	Troy, *Spencer*	6	75	*y*	*y*	75
20	Francisco, *Gibson*	5	80	*y*	200	280
21	Hudsonville, *Daviess*	5	0	0	4*xx*	4*xx*[6]
22	Bristow, *Perry*	5	120	0	55	175
23	Unionville, *Monroe*	5	0	0	2,200	2,200[6]
24	Sommerville, *Gibson*	5	*y*	0	*y*	*y*
25	Oaktown, *Knox*	4	20	0	7*xx*	7*xx*[6]
26	Vanderburgh, *Vanderburgh*	3	250	0	0	250
27	Blairville, *Posey*	0.6	300	0	0	300[6]
28	Total		12*x*,*xxx*	26,*xxx*	68*x*,*xxx*	83*x*,*xxx*

[a] Footnotes to column heads and explanation of symbols are on page 249.

[1] Adams, Wells, Huntington, Howard, Grant, Blackford, Jay, Randolph, Delaware, Madison, Tipton, Hamilton, Marion, Hancock, Henry, Rush, Shelby, Decatur counties.

[2] Abandoned 1908. [3] Abandoned 1904 because of litigation.

[4] Includes Marts, Shelburn, Heims, Dodds Bridge, Denny, Graysville, Harmonand Bragdon, Dix, Scott, and Edwards pools. [5] Includes several pools. [6] Field not completely outlined yet.

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The naming of fields and grouping of pools into fields is not entirely consistent with previous literature. Developments since the original naming of pools or fields as well as the form in which the data were available led us to make the changes in naming and grouping. In Sullivan County and in Pike and Gibson counties, a number of pools were treated in this manner.

Proration by pipe lines during the last quarter of 1934 reduced the expected total oil production about 5 per cent. The allowable for Pike, Gibson and Daviess county fields was 75 per cent from Oct. 1 to Dec. 1; 82 per cent from Dec. 1 to Dec. 18 and 82 per cent from then until Jan. 1. In Sullivan and Vigo counties the allowable was 75 per cent from Oct. 9 to Dec. 3 and 73 per cent on to the end of the year. The remainder of the state had no proration.

The old Trenton field, which reached its peak of 11,300,000 bbl. in 1904, declined steadily until 1934, when approximately 20,000 bbl. was produced. The oil is gathered entirely by tank trucks and distributed to industries in near-by towns, where it is used as a fuel. The producer receives $1.25 at the well for the oil. This condition has led to renewed

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production, M. Cu. Ft.				Number of Oil and/or Gas Wells		
	To End of 1934	During 1933	During 1934	Daily Average during Nov. 1934	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov. 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	During 1934	
													Completed	Abandoned
1	106,*xxx*,*xxx*	16,*xxx*	20,*xxx*	*y*	*y*	*y*	0.2	8*xx*,*xxx*	2*xx*	19*x*[7]	*y*	26,5*xx*	16	95
2	0	0	0	0	0	0	0	3,*xxx*	163	165[7]	0.5	5*xx*	0	0
3	1,5*xx*,*xxx*	0	0	0	8*xx*	*x*	0	0	0	0	0	3*xx*	0	0
4	2*x*,*xxx*	0	0	0	*x*	*x*	0	0	0	0	0	3*xx*	0	0
5	2*x*,*xxx*	0	0	0	333	*x*	0	*y*	7.6	7.6	0.5	45	1	2
6	1,3*xx*,*xxx*	7,2*xx*	8,0*xx*	22	1,495	*x*	0.7	*y*	0	0	0	148	0	13
7	*y*	30,*xxx*	26,*xxx*	72	*y*	*y*	7.0	*y*	0	0	0	136	0	2
8								2,4*xx*	309	268	0.6	110	1	4
9	6,4*xx*,*xxx*	50,*xxx*	74,*xxx*	202	*y*	*y*	0.6	9*xx*	46.2	49.5	0.4	1,070	8	11
11	*y*	153,*xxx*	150,*xxx*	412	60.6	*y*	2.5	*y*	11	28	0.08	373	4	11
12	22,*xxx*	2,6*xx*	2,2*xx*	6	*y*	*y*	1	*y*	584	703	2.2	86	3	7
13	*y*	192,9*xx*	222,4*xx*	554	*y*	*y*	2.8	0	0	0	0	240	13[10]	4
14	*y*	2,0*xx*	1,7*xx*	4.7	*y*	*y*	1.5	*y*	0	0	0	*y*	0	0
15	8*x*,*xxx*	17,2*xx*	17,*xxx*	47.5	5*xx*	*y*	3.1	0	0	0	0	20	0	2
16	*y*	16,4*xx*	13,1*xx*	36	*y*	*y*	1.5	0	0	0	0	54	0	0
17	1,747,*xxx*	168,*xxx*	172,*xxx*	470	3,45*x*	*y*	7.4	0	0	0	0	77	0	6
18	*y*	6,*xxx*	6,5*xx*	18	*y*	*y*	3	0	0	0	0	*y*	0	0
19	3*x*,*xxx*	12,*xxx*	16,*xxx*	44	400	*y*	2.2	0	0	0	0	26	5	0
20	25,*xxx*	*y*	6,*xxx*	20	625	*y*	5	1,1*xx*	220	77	0.3	24	2	2
21	0	0	0	0	0	0	0	*y*	44	89	0.6	15	5	1
22	35,*xxx*	11,*xxx*	8,7*xx*	28	290	*y*	1.2	0	0	0	0	33	7	2
23	0	0	0	0	0	0	0	0	0	0	0	13	2	0
24	18,*xxx*	2,0*xx*	5,8*xx*	16	*y*	*y*	2.3	0	0	0	0	11	0	4
25	9,*xxx*	0	9,*xxx*	35	45*x*	*y*	135	19	0.7	18	0.05	17	9	0
26	120,147	49,460	69,194	197	480	*y*	4	0	0	0	0	51	18	8
27	3,*xxx*	0	3,*xxx*	45	*y*	*y*	15	0	0	0	0	5	5	0
28	120,955,*xxx*	737,*xxx*	817,*xxx*[7]				1.9	8*xx*,*xxx*	1,585	1,595		*y*	99	174

[7] Bureau of Mines gives 810,000 barrels.

[10] Two were old wells deepened from the 1200-ft. "sand" to the 1700-ft. "sand."

pumping of a number of wells that had been shut down. Natural gas production, which was at its peak in 1900 in the Trenton field, has declined, as has the oil production. It is impossible to determine the number of gas wells in operation and the amount produced, because they are so widely scattered and a great part of the consumption is rural. Recent completions in Jay County are responsible for the only increase in production in the Trenton gas field. Decatur County, the southernmost in this field, has the largest supply at present.

TABLE 1.—(*Continued*)

	Number of Oil and/or Gas Wells					Average Depth, Ft.		Oil Production Methods at End of 1934		Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1934				
	At End of 1934							Number of Wells			Average at End of		Gravity A.P.I. at 60° F.				
Line Number	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[e]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Pumping	Air-lift	Initial	1933	1934	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	*y*	2*xx*	0	3*xx*	5*xx*	1,050–1,250	980–1,230	2*xx*	0	325	*y*	*y*	38	24	36	*y*	P
2	0	0	0	190[8]	190	907	886			*y*	127	125					
3	0	0	0	0	0	933	898	0	0				*x*	*x*	*x*	*x*	P
4	0	0	0	0	0	145	125	0	0				21	17	19	1.26	A
5	2	0	0	5	5	540	532	0	0	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
6	0	33	0	0	33	920	890	33	0	*y*			31	30	30.5	*y*	P
7	31	23	0	13	36	1,107	1,085	23	0	*y*	*y*	*y*	*y*	*y*	*y*	*y*	A
						1,126	1,112										
8	0	0	0	39	39	680	650			*y*	55	52					
9	10[9]	342	0	9	351	325	298										
						560[13]	545										
						667	640	342	0	*y*	*y*	*y*	35	25	31	*y*	M*y*
						775	730										
						810	800										
						2,285	2,270										
11	*y*	163	0	17	180	950	945										
						1,250	1,244	163	0	*y*	*y*	*y*	32	29	31	*y*	P
12	0	5	0	42	47	1,100	1,080										
						1,140	1,130	5	0	440	390	150	39	36	38	*y*	M
13	10	198	0	0	198	1,270[14]	1,250										
						1,360	1,340										
						1,295	1,270										
						1,740	1,725	198	0				*y*	*y*	32	*y*	P
14	*y*	3	0	0	3	1,734	1,728	3	0				*y*	*y*	*y*	*y*	P
15	0	15	0	0	15	1,335	1,317	15	0				36	32	34	*y*	P
16	0	24	0	0	24	1,169	1,161	24	0				*y*	*y*	*y*	*y*	P
17	21	36	0	1	37	2,125	2,100										
						2,194	2,175	20	37				*y*	*y*	45.9	*y*	P
18	0	6	0	0	6	1,320	1,310	6	0				*y*	*y*	36	*y*	M
19	2	18	0	2	20	728	714										
						758	747										
						827	805	18	0	*y*	*y*	*y*	*y*	*y*	34.7	*y*	P
20	12	5	1	4	10	1,450	1,430	5	0	590	545	540[15]	*y*	*y*	30	*y*	*y*
21	0	0	0	9	9	660	650			245	*y*	*y*					
22	9[11]	22	0	0	22	350	330	22	0	*y*	*y*	*y*	*y*	*y*	34	*y*	A
23	13[12]	0	0	0	0	850	800			250	*y*	*y*					
24	*x*	3	0	0	3	330	315										
						1,350	1,340	3	0	*y*	*y*	*y*	*y*	*y*	33	*y*	P
25	11	4	0	2	6	610	580	4	0	325	*y*	*y*	*y*	*y*	32	*y*	P
26	*y*	51	0	0	51	911	889										
						1,031	1,007	51	0				28	24	26	*y*	A
27	0	5	0	0	5	1,193	1,168	5	0				*y*	*y*	27	0.4	P
28	*y*	1,2*xx*	1	7*xx*	1,9*xx*			1,1*xx*	37								

[8] Many additional wells supplying very local markets.
[9] Gas wells.
[10] Two were old wells deepened from the 1200-foot. "sand" to the 1700-ft. "sand."
[11] Seven are gas wells.
[12] Have an available open flow of 12 million cubic feet. No market at present.
[13] Production is from one, two, three and/or four sands in same wells.
[14] Same well produces from more than one horizon.
[15] High because of water.

Decline in capacity of the Francisco gas field in Gibson County, and the consequent increased load placed on the Alford field in Pike County, led to considerable exploration for new gas supplies and development of already established fields in southwestern Indiana. The Francisco field, producing 77,000,000 cu. ft. last year, has declined without yielding nearly the amount of gas expected from it when it was developed. Adverse water conditions have been largely responsible for this. In the Oaktown gas field, in northern Knox County, nine gas wells were completed in 1934. Of these, and those brought in during the previous two years, only two are marketing gas. Preparations are being made to extend a new and larger pipe line into this field, which at the end of 1934 was only partly developed. Other developmental activity was seen in the Hudsonville gas field in southern Daviess County. Like the Oaktown field, this had not been completely outlined by the end of 1934.

The Vanderburgh County oil field was completely outlined during 1934 and has settled to steady production. Several completions in the

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1934		Producing Rock					Structure[j]	Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934		Reference to Text[k]
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.			Name	Depth of Hole, Ft.	
1	950+	*x*	Trenton	Ord	D, L	Por Fis	*x*	A	3,7*xx*	Pre-Cam	3,996	
2	847	*x*	Trenton	Ord	L & D	Por	*y*	*y*	*y*	*y*	3,055	
3			Trenton	Ord	L & D	20	*y*	*y*	*xx*	Trenton	1,041	
4			Unnamed	Dev	L	Por Fis	*x*	*y*	*x*	Trenton	1,010	
5	950	*x*	Chester	MisU	S	Por	*y*	A	28	"Mississippi"	783	
6	*y*	*x*	West Princeton	PenL	S	Pory	*y*	*y*	26	Chester	1,735	
7	*y*	*x*	Mooretown, Oakland City	MisU	S	Por	*y*	A	19	Paoli	1,444	P
8	954	0	New Albany	Dev	H	Fis	*y*	M	34	Trenton	1,770	
9	970	0	Unnamed	PenL								
			1st sand	PenL								
			2nd sand	PenL								
			3rd sand	PenL								
			4th sand	PenL	S	Por	*y*	MU*y*	651	"Niagaran"	2,328	P
			"Niagaran"	Sil	L	Por	*y*	*y*	*y*			
11	950	0	Cypress, Mooretown *y*	MisU	S, L	P	*y*	A	62	Paoli	1,632	P
12	*y*	0	Oakland City, Brown	MisU	S	P	*y*	A	32	"Miss" lime	1,413	
13			Sample-Paoli, Cypress-Paoli	MisU	S	P	*y*	A	44	Harrodsburg	2,050	P
14			Chester	MisU	S	P	*y*	*y*	*y*	Chester	2,105	P
15			Oakland City	MisU	S	P	*y*	*y*	12	Mooretown	1,352	P
16			Veale sand	MisU	LS	P	*y*	A	51	*y*	2,618	P
17			"Niagaran"	Sil	LS	P	*y*	*y*	10	Trenton	3,534	P
18			Bethel	MisU	S	P	*y*	MC	6	"Miss" lime	1,500	
19	*y*	0	Cypress, Mooretown	MisU	S	P	*y*	*y*	10	"Miss" lime	1,708	
20	957	0	"Brown" sand	MisU	S	20	15	A	5	Ord	4,006	
21	955	*y*	Elwren	MisU	S	P	*y*	*y*	16	"Miss" lime	1,021	
22	*y*	0	Cypress, Elwren	MisU	S	P	*y*	ML	15	"Miss" lime	710	
23	980	0	"Corniferous"	Dev	D	P	*y*	A	4	Trenton	2,102	
24	*y*	0	LPen-?	Pen?								
			"Oakland City"	Mis	S	P	*y*	A	10	"Miss" lime	1,638	P
25	952	0	Unnamed	PenL	S	P	*y*	M	11	Chester	1,593	
26	*y*	0	Mansfield	PenL	S	P	*y*	M	20	Glen Dean	1,795	
27			Mansfield	PenL	S	22	30	A	4	U Chester	1,580	
28									*y*			

Troy field in Spencer County increased the number of producing wells. Indications are that the Blairsville field, in Posey County, discovered in 1934, will be developed into a nice oil field. A number of wildcat wells drilled in Dubois County in the last eight months of 1934 failed to locate any noteworthy production.

No water drives or repressuring have been attempted in Indiana to date. One well in the Emmison lease in Johnson township, Knox

TABLE 2.—*Summary of Drilling Operations in Indiana*

(Figures in body of tabulation represent number of holes.)

	County	Completed Prior to Jan. 1, 1935							Completed during 1934					Drilling or Incomplete at End of 1934	
		Dry and/or Near-dry Holes						Productive Wells	Dry and/or Near-dry Holes				Productive Wells		
		Total Depths, Ft.							Total Depths, Ft.						
		0–1000	1000–2000	2000–3000	3000–4000	4000–5000	Total	(For Details See Table 1)	0–1000	1000–2000	2000–3000	Total	(For Details See Table 1)	Within Fields	Exploratory
	Northeast														
1	Adams	*x*[1]	22*x*	0	0	0	230	1802	0	1	0	1	0	0	0
2	Allen	0	3	0	0	0	3	34	0	0	0	0	0	0	0
3	Blackford	9*x*	28*x*	0	0	0	37*x*	1891	0	0	0	0	0	0	0
4	Cass	5	2	0	0	0	7	*x*	0	0	0	0	0	0	0
5	Decatur	*xx*[1]	1*x*	1	0	0	10*x*	3*xx*	0	0	0	0	1	0	0
6	Delaware	7*x*	5*xx*	0	0	0	6*xx*	2537	0	0	0	0	0	0	0
7	Dekalb	*x*	*x*	0	0	0	*x*	*x*	0	0	0	0	0	0	0
8	Franklin	0	3	2	0	0	5	0	0	0	0	0	0	0	0
9	Grant	3*xx*	2*xx*	0	0	0	61*x*	6258	0	0	0	0	0	0	1
10	Hamilton	2	*x*	0	0	0	1*x*	34	0	0	0	0	0	0	0
11	Hancock	*x*	*xx*	0	0	0	*xx*	1*xx*	2	0	0	2	2	0	0
12	Henry	*xx*	*x*	0	0	0	*xx*	*xx*	0	0	0	0	0	0	0
13	Howard	*xx*	*x*	0	1	0	*xx*	3*xx*	0	0	0	0	0	0	0
14	Huntington	3*x*	9*x*	0	0	0	13*x*	1988	0	0	0	0	0	0	0
15	Jasper	*xx*	*x*	0	0	0	*xx*	2*xx*	0	0	0	0	0	0	0
16	Jay	6*x*	50*x*	0	1	0	56*x*	2243	0	1	0	1	11	2	0
17	Jennings	0	1*x*	0	0	0	1*x*	12	0	0	0	0	0	0	0
18	Madison	27*x*	3*x*	0	0	0	30*x*	347	0	0	0	0	0	0	0
19	Marion	18	5	0	0	0	23	61	0	0	0	0	0	0	0
20	Miami	1*xx*	*x*	0	0	0	1*xx*	3*xx*	0	0	0	0	1	0	0
21	Randolph	*x*	27*x*	0	0	0	28*x*	542	0	0	0	0	1	0	0
22	Rush	*xx*	*x*	0	0	0	*xx*	1*xx*	0	0	0	0	0	0	0
23	Shelby	*xx*	*x*	0	0	0	*xx*	*xx*	0	0	0	0	0	0	0
24	Switzerland	3	2	0	0	0	5	4	0	0	0	0	0	0	0
25	Tipton	1	*x*	0	0	0	*x*	*xx*	0	0	0	0	0	0	0
26	Wabash	1*x*	3	0	0	0	1*x*	2*x*	0	0	0	0	0	0	0
27	Wells	8	29*x*	0	0	0	30*x*	4697	0	0	0	0	0	0	0
28	Fountain	0	2	1	0	0	3	0	0	0	0	0	0	0	0
	Southwest														
29	Davies	60	33	1	0	0	94	120	0	1	0	1	5	0	0
30	Dubois	1	12	1	0	0	14	13	7	0	0	7	1[2]	0	0
31	Gibson	3*x*	24*x*	4	1	1	27*x*	515	3	5	0	8	11	0	0
32	Green	*x*	3	2	0	0	5	2	0	0	0	0	0	0	1
33	Harrison	30	4	0	0	0	3*x*	110	0	0	0	0	1	0	0
34	Knox	49	22	3	0	0	74	49	4	2	0	6	9	0	0
35	Monroe	1	14	2	0	0	17	13	0	0	0	0	3	0	0
36	Perry	79	3	0	0	0	82	31	9	1	1	11	7	1	0
37	Pike	15*x*	2*xx*	2	0	0	35*x*	544	1	3	0	4	11	0	0
38	Posey	1	5	0	0	0	6	5	0	4	0	4	5	0	0
39	Spencer	26	42	0	0	0	68	42	2	1	0	3	5	0	0
40	Sullivan	4*xx*	2*xx*	1*x*	0	0	6*xx*	1070	3	1	1	5	8	0	0
41	Vanderberg	9	16	2	0	0	27	51	3	19	0	22	18	0	0
42	Vigo	*x*	21	17	1	0	39	95	0	0	0	0	1[2]	0	0
43	Warrick	1	21	1	0	0	23	2	0	0	0	0	1[2]	0	0
44	Washington	14	1	0	0	0	15	3	1	0	0	1	1[2]	1	0
	Totals	*y*	*y*	4*x*	4	1	*y*	*y*	35	39	2	81[3]	103	4	2

[1] *x* = 1 to 9; *xx* = 10 to 99. [2] Not within any field, therefore not in Table 1.
[3] Five were exploratory in counties not included above.

County, was treated with acid. A marked increase in production was noted, but details pertaining to it are lacking.

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Oil Development and Production of Kansas in 1934

By Marvin Lee,* Member A.I.M.E.

(New York Meeting, February, 1935)

Kansas retained, for the eighth consecutive year, the fourth position in the list of oil-producing states. The total crude-oil production during 1934, as reported by purchasers to the State Corporation Commission, was 45,538,564 bbl. on 97 per cent tank table calculations of the purchasers, or 46,946,973 bbl. as carried on 100 per cent measurement in U.S. Government reports. The corresponding figures for 1933 are 40,008,940 and 41,236,021, respectively.

The increase of production over 1933 was due to the rising demand for oil from Kansas, caused principally by three factors: the continued regulation of the producing branch of the industry by Federal and State authorities, which had the effect of reducing illegal production that has been so destructively competitive with Kansas crude and refined products; the normal decline of production in other areas; and, last and best, general increased demand of the public for petroleum products.

The price level remained unchanged for the first time in oil history for so long a period. Kansas 36° gravity crude remained at $1 per barrel from September, 1933, and throughout 1934. Price stability and the confidence in the regulation of production to meet the consumer demand, which is increasing, brought greatly renewed interest in Kansas fields.

Drilling activity has been largely in the western part of the state where expiration of leases, on large blocks of acreage, assembled before the depression, is forcing either action or loss of the lease investment carried for a long period. The drilling of these many blocks of acreage, previously assembled on geologic information, has caused the opening of more fields than during any previous year of Kansas oil history and is proceeding faster than anticipated a year ago. Interest grows within a successful enterprise, and the momentum caused by the successes of 1934 will continue in 1935 unless unusual conditions arise and end the apparently good opportunity for financial return.

Geological exploration methods used in new field discoveries are shown in the tabulation of new discoveries (Table 3).

Manuscript received at the office of the Institute April 15, 1935.

* Consulting Petroleum Geologist, Wichita, Kansas.

TABLE 1.—*Oil and Gas Production in Kansas*

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres (Approximate)				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	Daily Average Potential at End of 1934	Per Cent Allowed at End of December, 1934	During 1934 at 97% Tank Table Measurement	Daily Average during 1934
1	Abbyville, *Reno*	8.0	100	100	0	100	816	26.47	51,065	140
2	Atyeo-Pixlee, *Lyon-Greenwood*	9.1	1,000	0	0	1,000	382	88.79	118,815	326
3	Aldrich, *Ness*	6.0	10	0	0	10	*y*	00	0	0
4	Augusta North, *Butler*	18.0	1,250	0	0	1,250	1,384	86.41	379,135	1,039
5	Augusta South, *Butler*	18.0	11,000	0	0	11,000	1,542	86.41	427,558	1,171
6	Beaver, *Barton*	0.1	40	0	0	40	0	0	2,040	1
7	Bentley, *Sedgwick*	0.7	10	0	0	10	45	67.73	3,048	8.3
8	Benton, *Butler*	9	40	0	0	40	28	86.41	7,063	24
9	Beyer, *Rice*	4	100	0	10	100	744	48.73	144,159	395
10	Bison, *Rush*		40		40	40	*y*			
11	Brandenstein, *Rice*	1.1	40			40	2,770	16.29	137,841	378
12	Breford, *Ellis-Barton*	2.3	80			80	1,025	38.00	109,985	301
13	Browning, *Greenwood*		3,800			3,800	859	89.52	274,766	901
14	Burden, *Cowley*		1,200			1,200	799	77.07	149,752	410
15	Burkett, *Greenwood*		2,660			2,660	278	100	102,664	281
16	Burrton (Mis Ls), *Reno-Harvey*	3.8	5,000			5,000	9,141	38	1,125,653	3,084
17	Burrton (Hunton L), *Reno-Harvey*		3,000			3,000	29,661	11.49	329,450	903
18	Caldwell, *Sumner*	5.7	160			160	421	41.02	71,856	197
19	Carson, *Cowley*	9.3	400			400	310	86.41	102,074	280
20	Chase, *Rice*	2.1	1,000			1,000	25,443	25.30	1,661,152	4,551
21	Chindberg, *McPherson*	5.0	700			700	*y*			
22	Churchill, *Sumner*	8.5	1,000			1,000	1,382	80.18	425,987	1,167
23	Clark, *Cowley*		200			200	53	86.41	16,016	44
24	Climax, *Greenwood*		100			100	68	86.41	17,431	48
25	Coffey Miscellaneous, *Coffey*		150			150	37	89.52	10,984	30
26	Covert-Sellers, *Marion*		2,400			2,400	335	86.41	106,857	293
27	Cowley Miscellaneous, *Cowley*		500			500	385	89.52	95,017	260
28	Cross, *Sedgwick*	5.8	30			30	88	67.73	9,564	26
29	Curry (abandoned), *Sedgwick*	5.1	*y*			*y*	0			
30	Cunningham, *Kingman*	4.0	800	800		800	5,390	33.99	469,843	1,287
31	Davidson, *Barton*	4.8	10			10				
32	Demalorie-Souder, *Greenwood*		4,480			4,480	868	89.52	235,167	644
33	De Moss, *Butler*						33	73.95		
34	Denton, *Elk*		1,500			1,500	161	100	56,864	156
35	Dillner, *Russell*	4.7	40			40	74	70.84	10,243	28
36	Dopita, *Rooks*	0.6	40			40	*y*			0
37	Douglass, *Butler*		2,400			2,400	178		56,111	153
38	Eastborough, *Sedgwick*	5.3	1,000			1,000	1,795	70.84	487,678	1,336
39	Eastman, *Cowley*		700				307	89.52	93,542	256
40	East Kansas (Shallow), Several counties in E. Kansas		250,000			250,000	5,975	100.00	2,045,034	5,602
41	Elbing, *Butler*	16.2	1,800			1,800	1,266	83.29	422,355	1,157
42	El Dorado, *Butler*	19.3	26,000			26,000	13,475	89.52	4,348,745	11,914
43	Elk West, Miscellaneous, *Elk*		1,000			1,000	204	89.52	99,280	272
44	Ellinwood, *Barton*	2.5	160			160	3,926	29.08	299,232	819
45	Eureka Townsite, *Greenwood*		1,200			1,200	60	100.00	21,861	60
46	Fairport, *Russell*	11.1	2,000			2,000	5,505	67.73[1]	1,412,620	3,870
47	Fairport North, *Russell*	6.5	200			200		[1]		
48	Fairport South, *Russell-Ellis*	8.7	1,500			1,500		[1]		
49	Fall City, *Cowley*		400			400	60	100.00	22,963	62
50	Fankhouser, *Greenwood-Lyon*		2,500			2,900	194	100.00	66,357	182
51	Ferguson, *Elk-Cowley*		400			400	958	46.78	99,595	273
52	Fink, *Russell*	0.1	40			40	298	30.93	976	2.6
53	Florence-Urschell, *Marion*		3,000			3,000	248	86.41	47,997	131
54	Fox-Bush, *Butler*		5,000			5,000	734	100.00	236,958	649
55	Garden-Shaffer, *Butler*		1,600			1,600	1,269	83.29	358,766	983

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[a] Footnotes to column headings and explanation of symbols are on page 249.

[1] Fairport production represents total for Fairport, North Fairport, South Fairport.

TABLE 1.—(*Continued*)

	Number of Oil and/or Gas Wells								Average Depth, Ft.		Oil Production Methods at End of 1934		Character of Oil Approx. Average during 1934
		During 1934		At End of 1934							Number of Wells		
Line Number	Completed to End of 1934	Completed	Deepened	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[e]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gravity A. P. I. at 60° F., Weighted Average
1	3	1	0	0	3	3	0	3	3,539	3,530	0	3	37
2	70	0	0	0	70	0	0	70	2,330	2,360	0	70	
3	1	0	0	1	0	0	0	0	4,430		0	0	33
4		2	0	*y*	*y*	*y*	*y*	114					
5		3	0	*y*	*y*	*y*	*y*	150					
6	1	0	0	0	1	0	0	1	3,351				38
7	1	1	0	0	1	0	0	1	2,911				34
8								2		2,850			
9			0		8	0	0	8	3,250				42
10							1						
11	2	0	1	0	2	0	0	2	3,026				42
12	7	3	0	0	7	0	0	7	3,040 3,407				45
13		1	0	*y*	*y*	*y*	*y*	119					
14		6						27					
15								93					
16		22	2				2	52	3,400 3,597				31
17		12	1	1				12	3,597				42
18	4	0	0	0	3	0	0	3	4,790				47
19								22					
20	51	25	0	0	51	0	0	51	3,290				42
21	10	5	0						3,025				
22					67	0	0	67	1,820				37
23								4					
24								5		1,850			
25								7					
26								23					
27								42					
28	3	2	0	0	3	0	0	3	2,690				35
29	1	0	0	0	0	0	0	0	3,390				41
30	24	10	0	0	1	23	0	24	3,455				36
31	1	0	0	1	0	0	0	Shut in	3,340				
32								137					
33	1	1	0	0	1	0	0	1					
34								41					
35	2	0	0	0	2	0	0	2	3,310				30
36	1	1	0	1	0	0	0	Shut in	3,419				35 27
37		3	0	*y*	*y*	*y*	*y*	22					
38	58	6	1	*y*	49	0	0	49	2,927 3,235				44
39								35					
40								11,342					
41								71					
42		4	*y*	*y*	*y*	*y*	*y*	1,763					
43								24					
44	12	8	0	0	12	0	0	12					
45		1	0	*y*	*y*	*y*	*y*	16					
46	110	4	5		95	0	0	95	3,300	2,950			40
47	7	1	0		6	0	0	6	3,204	3,070			40
48	38	4	0		35	0	0	35	3,030				40
49								17					
50								80					
51								9					
52	1	1	0	1	0	0	0	Shut in	3,170				36
53		1	0	*y*	*y*	*y*	*y*	17					
54								208					
55		2	0	*y*	*y*	*y*	*y*	80	3,000 3,050 3,150				36

TABLE 1.—(*Continued*)

Line Number	Producing Rock					Number Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Name as Used Locally[1a]	Age[g]	Character[h]	Porosity[i]	Structure[j]		Name	Depth of Hole, Ft.
1	Lansing-Kansas City	Pen	L			1	Lansing-Kansas City	3,588
2	Bartlesville sand	Pen	S			y	Mis Ls	2,700(?)
3	y	y	S			0	y	
4	y	y	S		A	y	Pre-Cam	
5	y	y	S		A	y	Pre-Cam	
6	Siliceous Ls	Cam-Ord	D		AM	0	"Siliceous" Lime	
7	Kansas City	Pen	L		MT	0	Ord	
8	"Chat"	Mis	L, Cav			y		
9	Conglomerate and Siliceous Ls[8]	Pen, Cam-Ord	L, Cav		A	3	"Siliceous" Lime	
10	Reagan Ss	Cam	S	Por	D	y	Cam	
11	Lansing-Kansas City	Pen	L			6	"Siliceous" Lime	
12	"Oswald" Lime,[9] Siliceous Ls	Pen, Cam-Ord	L, D		AM	1	Pre-Cam	
13	Bartlesville sand	Pen	S		ML	y	y	
14	Bartlesville sand	Pen	S		D	y	y	
15	Bartlesville sand	Pen	S		ML	y	y	
16	Mississippi Lime	Mis	L		Af		"Siliceous" Lime	
17	Hunton Ls	Sil-Dev	D		Af		"Siliceous" Lime	
18	"Wilcox" sand	Ord	S		D	1	Ord	
19	Layton sand—Sil Ls	Pen, Cam-Ord				y	y	
20	"Siliceous" Lime	Cam-Ord	D		A	4	"Siliceous" Lime	
21	Mississippi "Chat"	Mis	L Cav		A	2	Ord	
22	Stalnaker sand	Pen	S		D	13	"Stalnaker" sand	
23	Bartlesville	Pen	S		ML	y	y	
24	Mississippi lime	Mis	L		MT	y	y	
25	y	y	y		y	y	y	
26	Viola(?)	Ord	L-D		AM	y	y	
27	y	y	y		y	y	y	
28	Kansas City-Lansing	Pen	L			2		
29	Simpson	Ord	D			5	Ord	
30	Lansing-Kansas City	Pen	L		D	2	"Siliceous" Lime	
31	"Siliceous" lime	Cam-Ord	D		AM	0		
32	Bartlesville	Pen	S			y	y	
33	Bartlesville	Pen	S		ML	y	y	
34	Mississippi lime	Mis	L				y	
35	"Siliceous" lime	Cam-Ord	D			0	y	
36	Lansing-Kansas City Ls	Pen	L					
	Siliceous lime	Cam-Ord	D			0	y	
37	Lansing-Kansas City Ls	Pen	L					
	y	Ord	y		A	y	y	
38	Mississippi lime	Mis	L		D	12		
	Viola lime	Ord	D					
39	Bartlesville sand	Pen	S		D	y		
40	Several horizons; most are sands	Pen	S		D	y		
			L		A			
					ML			
41	Viola or "Siliceous" Ls	Ord or Cam-Ord	D		D	y		
42	Penn sands and limes	Pen	S, L		D-Af	y	Pre-Cam	
	Mississippi Ls	Mis						
	Viola, "Wilcox" "Siliceous" Ls	Ord-Cam-Ord	D-S-LS					
43	Mississippi, lime	Mis	L		y	y		
44	"Siliceous" lime	Cam-Ord	D			2		
45	Mississippi lime	Mis	L		A	y		
46	"Oswald" lime	Pen	L		A	8		
47	"Oswald" lime	Pen	L		A	4		
48	"Oswald" lime	Pen	L		A	6		
49	Kansas City lime	Pen	L			y		
50	Bartlesville sand	Pen	S		ML	y		
51	Lansing-Kansas City	Pen	L		AM	y		
52	Lansing-Kansas City	Pen	L			0		
53	Viola or "Siliceous" Ls	Ord or Cam-Ord	D		AM	y		
54	Bartlesville sand	Pen	S		ML	y	"Siliceous" lime	
55	Bartlesville sand	Pen	S					
	Mississippi Ls	Mis	L			y		
	Viola Ls	Ord	D					

[1a] "Siliceous" Lime is frequently referred to as Arbuckle, Cam-Ord.
"Oswald" is a local name for production in Lansing-Kansas City Lime-Pen.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres (Approximate): Oil	Oil and Gas[a]	Gas	Total	Total Oil Production, Bbl.: Daily Average Potential at End of 1934	Per Cent Allowed at End of December, 1934	During 1934 at 97% Tank Table Measurement	Daily Average during 1934
56	Gates, *Stafford*	1.5	320			320	1,960	25.30	80,744	221
57	Geneseo, *Rice*	0.5	40			40	5,020	15.43	59,154	162
58	Geneseo Townsite, *Rice*	0.1	10			10	*y*		525	*y*
59	Gideon, *Russell*	4.5	40			40	25	80.18	10,946	30
60	Goodrich, *Sedgwick*	6.1	260			260	868	53.65	202,824	556
61	Gorham, *Russell*	8.2	1,500			1,500	4,115	48.73	497,399	1,362
62	Gorham (Deep Sand), *Russell*		250			250	187	77.07	31,263	86
63	Graber, *McPherson*	0.5	50			50	1,981	18.86	38,822	106
64	Graham, *Cowley*		300			300	160	86.41	51,864	142
65	Greenwich, *Sedgwick*	5.6	400			400	5,846	39.91	896,933	2,457
66	Greenwalt, *Rush*	3.4	10			10	*y*		*y*	*y*
67	Greenwood Miscellaneous, *Greenwood*		1,000			1,000	99	100.00	31,858	87
68	Grove, *Rice*	0.5	2,000			2,000	8,247	18.86	76,802	210
69	Hadley, *Ellis*	5.4	10			10	24	53.65	4,434	
70	Hall, *Russell*	3.5	120			120	594	23.00		*y*
71	Halstead, *Harvey*	5.7	160		320	320	142	53.65	29,615	81
72	Hamilton, *Greenwood*		3,000			3,000	770	89.52	261,240	716
73	Hanna, *Elk*		400			400	50	100.00	21,006	57
74	Haury (Mis Ls), *Reno*	4.3	2,000			2,000	1,782	38.92	236,719	649
75	Haury (Hunton L), *Reno*		3,000			3,000	42,724	13.81	416,835	1,142
76	Haverhill, *Butler*	8.0	700			700	450	89.52	150,802	413
77	Hazlette, *Butler*						44	86.41	7,436	20
78	Heiken[2], *Ellsworth*	4.2	40			40	269	56.87	61,511	168
79	Hesston, *Harvey*	0.3	40			40	124	48.73	3,354	9.2
80	Hilger, *Reno*	0.7	100			100	978	25.30	47,122	129
81	Hillsboro, *Marion*	6.2	300			300	709	60.88	156,248	429
82	Hittle, *Cowley*		300			300	140	89.52	42,418	162
83	Hollow, *Harvey*	3.0	1,500				19,231	38.00	3,379,788	9,260
84	Howard, *Elk*		160			160	16	100.00	4,773	13
85	Isern, *Rice-Barton*	3.1	40			40	1,968	25.30	147,063	402
86	Johnson, *McPherson*	2.8	1,000			1,000	5,830	36.36	675,930	1,852
87	Kechi, *Sedgwick*	5.6	10			10	144	41.02	10,013	27
88	Keighley, *Butler*	9.0	1,600			1,600	226	100.00	81,672	224
89	Kramer, *Butler*	8.0	500			500	1,167	70.84	286,725	785
90	Kruse (Abandoned), *Rooks*	7.0	*y*			*y*	*y*			
91	Kuske, *Sedgwick*	5.9	10			10	21	80.18	6,560	18
92	Lamont, *Greenwood*	7.0	2,600			2,600	481	100.00	174,473	478
93	Lanterman, *Barton*	0.1	10			10	0	0	0	0
94	Laton, *Rooks*	7.5	30			30	109	70.84	17,092	47
95	Latta, *Sumner*	7.5	300			300	152	80.18	45,275	124
96	Leon, *Butler*		500			500	96	100.00	32,098	88
97	Lorraine, *Ellsworth*	0.1	10			10	526	24.29	628	20
98	Lost Springs, *Marion*	8.0	2,400			2,400	567	86.41	127,543	349
99	Madison, *Greenwood*		3,000			3,000	1,010	89.52	302,383	828
100	McCarty, *Edwards*	5.5	80			80	20	89.52	3,028	8.3
101	McPherson, *McPherson*	6.7	2,000				196	83.29	32,762	90
102	Miller, *Russell*	2.7	?				214	46.78	34,995	96
103	Moline Townsite, *Elk*		300			300	261	89.52	85,231	233
104	Murphy, *Cowley*		40			40	*y*	0	0	0
105	Neola (Abandoned), *Stafford*	0.7	10			10	0	0	4,837	13

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[2] Initial pressure, 3234 lb. per sq. in.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells								Average Depth, Ft.		Oil Production Methods at End of 1934		Character of Oil Approx. Average during 1934
		During 1934		At End of 1934							Number of Wells		
	Completed to End of 1934	Completed	Deepened	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gravity A. P. I. at 60° F., Weighted Average
56	4	3	0	0	4	0	0	4	3,705				*y*
57	3	3	0	0	3	0	0	3	3,172				39
58	1	1	0		1	0	0	1	3,239				38?
59	1	0	0	0	1	0	0	1	3,329				36
60	14	1	0	0	14	0	0	14	2,616 3,350				37
61	35	9	0	0	35	0	0	35	3,065				34
62	6	0	0	0	6	0	0	6	3,317				37
63	2	2	0	0	2	0	0	2	3,305				41
64								15					*y*
65		4	1	*y*	*y*	*y*	*y*	38	2,850 3,327				*y*
66				1					3,428				43
67					38			38					
68		5	0		7			7	3,241				47
69					1			1					
70					2			2					
71					2			2	3,000				35
72					90			90					
73					19			19					
74					11	*y*		11	3,350				39
75		21	1	0	*y*	*y*	0	21					42
76			*y*	*y*	*y*	*y*	*y*	65					
77								4					
78	4	0	0		4	0	0	4					39
79	2	2	0	0	2	0	0	2	3,356				40
80	2	2	0	0	2	0	0	2	4,067				40
81								12	2,805				42
82								16					
83	112	23	29	0	106	*y*	0	106	3,517				43
84								4					
85	4	1	0	0	4	0	0	4	3,329				46
86		2	0	*y*	*y*	*y*	*y*	31	3,000				37
87		4	0	*y*	*y*	*y*	*y*	1					
88								68					
89								30	3,060				36
90								1					
91								1					
92								106					
93		1	0	0	0	0	0	0	3,255				42
94		1	0					3	3,125				30
95								7	3,040				40
96								27					
97		1	0					1	3,205				41
98		2	0	*y*	*y*	*y*	*y*	48					
99					119	*y*	*y*	119					
100								2	4,545				35
101		3	0					8	3,000				37
102		1	0					2					
103		3	0	*y*	*y*	*y*	*y*	33					
104		1	0	0	1	0	0	0					
105		1						1					

TABLE 1.—(*Continued*)

Line Number	Producing Rock					Number Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Name as Used Locally[1a]	Age[g]	Character[h]	Porosity[i]	Structure[j]		Name	Depth of Hole, Ft.
56	"Siliceous" Ls	Cam-Ord	D		A	4		
57	"Siliceous" Ls	Cam-Ord	D		D	0		
58	Basal conglomerate	Pen	S		A	0		
59	Lansing-Kansas City	Pen	L			2		
60	Kansas City L	Pen						
	Mississippi lime	Mis	L					
	Viola lime	Ord	D		D	7		
61	"Oswald" lime	Pen	L		D	10	Pre-Cam	
62	"Granite Wash"							
	Pen conglomerate	Pen	GW			*y*		
63	Hunton lime	Ord	D			0		
64	Layton sand	Pen	S			*y*	"Siliceous" lime	
65	Mississippi lime	Mis	L		D	20	"Wilcox" sand	
	Viola lime-"Wilcox"	Ord	D-S					
66	Basal conglomerate	Pen	S		D	1		
67	Mississippi, Viola Ls	Mis	L					
		Ord	D		AM	*y*		
68	Lansing-Kansas City	Pen						
	"Siliceous" lime	Cam-Ord	A			0		
69	Lansing-Kansas City		A			1		
70	Lansing-Kansas City	Pen	L					
	Basal Pen conglomerate	Pen	GW			0		
71	Mississippi "chat"	Mis	L		D	5		
72	Bartlesville sand	Pen	S		ML	*y*		
73	Lansing-Kansas City	Pen	L			*y*		
74	Mississippi "chat"	Mis	L	Cav	Af		"Siliceous" lime	
75	Hunton lime	Ord	D		Af			
76	Bartlesville sand	Pen	S		ML	*y*		
77	Mississippi lime	Mis	L		AM	*y*		
78	"Siliceous" lime	Cam-Ord	D			0		
79	Hunton lime	Ord	D		A	0		
80	Viola lime	Ord	D		A	1		
81	Viola lime	Ord	D		D	*y*		
82	Lansing-Kansas City	Pen	L			*y*		
83	Lansing lime,	Pen						
	Mississippi lime,	Mis	L					
	Hunton Ls, Wilcox sand	Ord	S		Af	9		
84	*y*	*y*	*y*		*y*	*y*		
85	Siliceous lime	Cam-Ord	D		AM	4		
86	Mississippi "chat"	Mis	L Cav		A	6		
87	Basal Pen	Pen	S		ML	4		
88	Bartlesville	Pen	S		ML	*y*		
89	Viola	Ord	D		MC	*y*		
90	*y*					0		
91	Basal Pen	Pen	S		ML	4		
92	Bartlesville	Pen	S		ML	*y*		
93	Siliceous Ls	Cam-Ord	A		AM	0		
94	Lansing-Kansas City	Pen	L		D	4		
95	Lansing-Kansas City	Pen	L		A	6		
96	Bartlesville	Pen	S		ML	*y*		
97	"Siliceous" lime	Cam-Ord	D		AM	0		
98	Mississippi "chat"	Mis	L Cav		MT	*y*		
99	Bartlesville	Pen	S		ML	*y*		
100	Basal Pen Conglomerate	Pen	L Cav		A	0	"Siliceous" lime	
101	Lansing-Kansas City	Pen	L		D	6		
	Mississippi "chat"	Mis	L Cav					
102	*y*	*y*	*y*		*y*	*y*	*y*	
103	Mississippi lime	Mis	L		*y*	*y*	*y*	
104								
105	Viola lime	Ord	D		*y*	0		

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres (Approximate)				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	Daily Average Potential at End of 1934	Per Cent Allowed at End of December, 1934	During 1934 at 97% Tank Table Measurement	Daily Average during 1934
106	Niedenthal, *Russell*	0.3	80			80	1,575	23.00	0	0
107	Nikkel, *Harvey-McPherson*	2.2	1,200			1,200	27,858	23.00	2,103,035	5,672
108	Ochs, *Russell*	5.1	400			400	3,097	28.20	159,430	437
109	Orth, *Rice*	2.5	600			600	635	43.58	110,301	302
110	Otis, *Rush*	0.5	10				27	39.91	4,009	11
111	Oxford, *Sumner*	7.5	600			600	1,024	83.29	335,672	920
112	Oxford-West, *Sumner*	8.5	100			100	87	83.29	25,293	69
113	Padgette, *Sumner*	9.5	300			300	570	80.18	141,691	388
114	Peabody, *Marion*	16.0	3,000			3,000	329	89.52	98,397	269
115	Plainville, *Rooks*		10			10	*y*	0	0	0
116	Ploog, *Rice*	4.4	160			160	1,278	23.00	51,259	140
117	Potwin, *Butler*		3,000			3,000	1,692	77.07	307,929	844
118	Quincy, *Greenwood*	8.0	3,500			3,500	323	89.52	119,840	328
119	Rainbow Bend, *Cowley*	10.1	2,000			2,000	1,306	86.41	402,199	1,102
120	Rainbow Bend West, *Cowley*	9.6	60			60		86.41		
121	Rapp, *Sedgwick*		10			10	27	77.07	6,439	18
122	Raymond, *Rice*	5.4	600			600	12,959	25.30	786,738	2,155
123	Rega, *Trego*	5.6	40			40	*y*	0	0	0
124	Reece, *Greenwood*		1,200			1,200	249	83.29	61,623	169
125	Richardson, *Stafford*	4.3	400			400	5,852	23.00	398,126	1,090
126	Ritz, *McPherson*	5.4	13,000			13,000	15,559	50.99	4,589,650	12,574
127	Rock, *Cowley*		200			200	84	100.00	30,253	83
128	Robbins, *Sedgwick*	5.6	800			800	7,711	30.93	355,880	97.5
129	Russell, *Russell*[3]	0.9	400			400	13,805	16.79	191,252	53
130	Russell (Oswald), *Russell*		100			100	1,457	21.60	24,166	66
131	Sallyards, *Greenwood-Butler*		7,700			7,700	865	10.00	308,145	844
132	Schulte, *Sedgwick*	0.7	10			10	209	35.28	25,613	70
133	Scott, *Greenwood*		2,500			2,500	299	100.00	112,070	307
134	Seeley, *Greenwood*		7,000			7,000	1,486	100.00	537,072	1,471
135	Sellens, *Russell*	5.5	1,200			1,200	1,889	41.02	207,132	567
136	Severy, *Greenwood-Elk*		200			200	18	100.00	6,258	171
137	Sharpe, *Rice*	3.8	700		10	700	15,540	23.00	875,946	2,351
138	Shallow Water, *Scott*	0.1	160			160	572	24.29	0	0
139	Shutts, *Ellis*	6.1	100			100	934	53.65	160,431	440
140	Smith, *Cowley*		200			200	96	89.52	27,456	75
141	Smock-Sluss, *Butler*		1,500			1,500	214	100.00	79,985	219
142	Sperling, *Harvey*	0.0	10			10	0	0	0	0
143	State, *Cowley*		400			400	294	86.41	66,071	181
144	Steckel, *Rice*	2.8	40			40	210	46.78	34,866	58
145	Steinhoff, *Butler*		30			30	125	43.58	0	0
146	Stoltenberg, *Ellsworth*	3.5	200			200	9,631	25.30	614,898	1,685
147	Stone, *Reno*	0.3	40				355	24.29	9,739	
148	Stratmann, *Ellsworth*	3.7	200				1,325	53.65	352,551	
149	Straub, *Barton*	0.4	40				45	67.73	191	
150	Sumner: Miscellaneous, *Sumner*	*y*	120				25	89.52	7,287	
151	Teter, *Greenwood-Chase*		2,600				952	100.00	314,941	
152	Thode, *Rice*	1.3	120				1,061	24.29	56,115	
153	Thrall, *Greenwood*		7,000				865	100.00	307,562	
154	Valley Center, *Sedgwick*[4]	6.4	1,500				3,260	64.62	741,610	
155	Virgil, *Greenwood*		18,000				1,724	100.00	631,962	

[3] Russell wells, tabulated last year, typographical error; 46^2 should have been 4^2.

[4] All drilling, 1934, was to Kansas City lime which was acid treated.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells								Average Depth, Ft.		Oil Production Methods at End of 1934		Character of Oil Approx. Average during 1934
		During 1934		At End of 1934							Number of Wells		
	Completed to End of 1934	Completed	Deepened	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gravity A. P. I. at 60° F., Weighted Average
106		3	0					3	3,255				40
107		21	3					50	3,460				43
108		7	0					10	3,370				36
109		2	0		5		1	6	3,238				42
110		4	0				3	1					
111		1	3					63	2,100				37
112	6			y	4	0	y	4					
113	24	1	0	y	23	y	y	23					
114								42					
115								1					
116	2	0	0	0	2	0		2	3,253				47
117		11						48					
118		2	0	y	y	y	y	55	1,450				
119								118	3,225				
120	12							7					
121		0						1					
122	32	14						30					
123	1	0	0	0	1	0		1					
124								15					
125	10	4	0	0	10			10					
126	319	70	11	y	y	y	y	268					
127								17					
128	26	17	0	0	0	26	0	26					
129	12	12	0	0	12	0	0	12	3,286				33
130	2	2	0	0	2	0	0	2	3,204				38
131		3	0	y	y	y	y	242					
132	1	1	0	0	1	0	0	1	3,652				42
133								74					
134		6	0	y	y	y	y	330	1,850				
135	14	5						14					
136	y	y	0	y				9					
137	29	27	0	0	28	0	1	28					
138	1	1	0	0	0	0	0	Shut in 0	4,686				25
139	12	1	0	0	11	0	0	11					
140							y	10					
141								48					
142	1	0	0	1	0	0	0	Shut in	3,345				35
143	1	1	y	y	y	y	y	22					
144	2	1	1	0	2	0	0	2					
145	1	1	0	0	1	0	0	1					
146	18	5	0	y	16	0	0	16					
147	1	2	0					1	3,386				42
148	18	3	0					18					
149	1	1	0	1				1	3,313				42
150								3					
151		6	0	y	y	y	y	203					
152	3	2	0					2	3,380				36
153								318					
154	137	10	0					71	3,375				43
155		15	0	y	y	y	y	490					

TABLE 1.—(*Continued*)

Line Number	Producing Rock					Number Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Name as Used Locally	Age[g]	Character[h]	Porosity[i]	Structure[j]		Name	Depth of Hole, Ft.
106	"Siliceous" lime	Cam-Ord	D		AM	0		
107	Hunton lime	Sil Dev	D		AL	5		
108	"Siliceous' lime	Cam-Ord	D		AM			
109	Basal sand	Pen	S		AM			
110	Reagan sand	Cam	S		AM	0		
111	Topeka lime	Pen	L		D	20		
	Stalnaker sand		S					
112						0		
113	Mississippi lime	Mis	L		A	12		
114	Viola or "Siliceous" Ls	Ord or Cam-Ord	D		AM	y		
115	"Siliceous" Ls	Cam-Ord						
116	Siliceous Ls	Cam-Ord	D		AM	0		
117	Mississippi "chat"	Mis	L		MT	y		
118	Bartlesville sand	Pen	S			y		
	Mississippi lime	Mis	L					
119	Bartlesville sand	Pen	S		ML	y		
120	y					6		
121	y							
	Kansas City-Lansing	Pen	L		AM	3		
122	"Siliceous" lime	Cam-Ord	D					
123	y					1		
124	Mississippi lime	Mis	L		A	y		
125	"Siliceous" lime	Cam-Ord	D		AM	1		
						40		
126	Lansing lime	L	L					
	Mississippi "chat"	Mis	L					
	Viola lime	Ord	D					
	"Wilcox" sand	Ord	S			y		
127	Bartlesville sand	Pen	S		D			
128	Mississippi lime	Mis	L		D	9		
129	"Siliceous" lime	Cam-Ord	D		D	y	Siliceous lime	
130	"Oswald" lime	Pen	L		D	1		
131	Bartlesville sand	Pen	S		ML	y		
132	Viola lime	Ord	D		y	2		
133	Bartlesville sand	Pen	S		ML	y		
134	Bartlesville sand	Pen	S		ML	y		
135	"Siliceous" Lime	Cam-Ord	D		AM	5		
136	Mississippi lime	Mis	L			y		
137	"Siliceous" lime	Cam-Ord	D		A	2		
138	Mississippi lime	Mis	L		D	0		
139	Kansas-City-Lansing lime	Pen	L					
	"Siliceous" lime	Cam-Ord	D		A	5		
140	Lansing lime	Pen	L			y		
141	Bartlesville sand	Pen	S		ML	y		
142	y					0		
143	"Siliceous" lime	Cam-Ord	D		D	y		
144	"Siliceous" lime	Cam-Ord	D		AM	0		
145	Lansing-Kansas City	Pen	L	Por	D	y	Mississippi lime	
146	"Siliceous" lime	Cam-Ord	D		AM	5		
147	Mississippi "chat"	Mis	L	Cav	A	0		
148	"Siliceous" lime	Cam-Ord	D	Por	AM	6		
149	"Siliceous" lime	Cam-Ord	D	Por		0		
150	Chiefly Mississippi lime	Mis	L	Por	A	y		
151	Bartlesville sand	Pen	S	Por	ML	y		
152	Mississippi lime	Mis	L	Cav	AM	0		
153	Bartlesville sand	Pen	S	Por	ML	y		
	Lansing-Kansas City	Pen	L	Por				
154	Viola lime	Ord	D	Por	D	17		
	Bartlesville sand	Pen	S	Por				
155	Mississippi lime	Mis	L	Por	D	y		

Development during 1934 is shown in reports and tables. Those interested in making direct comparisons for the various areas may do so by comparing these data with the corresponding paper in Volume 107 of the TRANSACTIONS.

The number of new discoveries during 1934 was greater than normal because of the conditions mentioned previously regarding the cause of drilling and the increase in production, and to the natural decline of some other areas, all of which made additional drilling necessary to supply needed oil. Thirty-six new producing fields were discovered, including four gas fields and three new oil-producing horizons in old fields. New areas as a result of wildcatting numbered 31. New discoveries, made by drilling to deeper horizons, are shown in the tabulated reports of the separate fields.

Production extension was chiefly in western Kansas fields. The potentials of the fields and new drilling for the year are shown in Table 1.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres (Approximate)	Total Oil Production, Bbl.			Number of Oil and/or Gas Wells							
								During 1934		At End of 1934				
			Oil	Daily Average Potential at End of 1934	Per Cent Allowed at End of December, 1934	During 1934 at 97% Tank Table Measurement	Completed to End of 1934	Completed	Deepened	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
156	Voshell, *McPherson*	5.3	3,500	1,273	46.78	2,409,845	146	11	0					116
157	Wakeeney, *Trego*[5]	0.5	160	882			2	2	0					2
158	Walton, *Harvey*	15.5	80	17	83.29	5,451	10							1
159	Weaver, *Butler*	4.2	160	21	100.00	6,685								8
160	Webb, *Elk*		2,000	474	89.52	172,940		8	0	*y*	*y*	*y*	*y*	94
161	Webster, *Rooks*[4,6]		40	264	31.85	1,991	2	1	0					1
162	Welch, *Rice*	10.9	1,500	1,856	56.87	290,429	40	2	0					29
163	Wellington, *Sumner*	5.1	100	800	36.36	80,472	5	1	0					5
164	Whelan, *Barber*	0.3	160	231	33.99	6,307	1	1	0					1
165	Wiggins, *Greenwood*		2,500	223	100.00	79,964		1	0	*y*	*y*	*y*	*y*	68
166	Wilkerson, *Greenwood*		1,300	188	89.52	61,320								36
167	Wilkins, *Ellsworth*	0.6	40	901	30.01	32,279	3	4	0					3
168	Winfield East, *Cowley*		5,000	947	86.41	250,968		4	0	*y*	*y*	*y*	*y*	90
169	Winfield Townsite, *Cowley*		300	1,152	83.29	331,560								56
170	Winterscheid, *Woodson*		7,700	900	100.00	311,678								184
171	Woodson Miscellaneous, *Woodson*		1,000	40	100.00	15,122		11	0	*y*	*y*	*y*	*y*	9
172	Yocemento, *Ellis*	5.4	40	14	86.41	118	4		0	*y*	*y*	*y*	*y*	4
173	Young, *Butler*	14.5	400	280	86.41	79,782	1							19
174	Voghts, *McPherson*[7]							2	0					2
175	Miscellaneous, *Ellsworth*						2	1	0				2	2

[5] Wakeeney—One well potential only.
[6] Webster—High lubrication content crude.
[7] Voghts prorated with Ritz in 1934.

The Burden pool in Cowley County had development extended toward the southeast. Dan Patton et al. No. 1 Hall, NW.¼ SW.¼ sec. 29-31-6E., had an initial production of 435 bbl. from the Bartlesville sand, completion date, June 30, 1934. Six wells were drilled as a result of this extension discovery.

Results from acid treatment of wells producing from limestone encouraged new development in several parts of eastern Kansas. Eleven wells were drilled and acid-treated in Potwin field of Butler County, four in the Eldorado pool, and several in areas that produced from limestone in Elk and Chautauqua counties.

Proration continued throughout 1934 under the direction of the State Corporation Commission. The system of proration used in Kansas applied to fields with greater than 5 bbl. daily average, with a very slight proration on the fields having small daily average potential and increasing cuts in allowable on those with larger well average potential. This system has proved uniformly satisfactory, although it had some criticism when initiated and until it became understood by producers.

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.	Character of Oil Approx. Average during 1934	Producing Rock					Number Dry and/or Near-dry Holes to End of 1934
	Bottoms of Productive Wells	Gravity A. P. I. at 60° F., Weighted Average	Name as Used Locally	Age[g]	Character[h]	Porosity[i]	Structure[j]	
156	3,000	42	Mississippi "chat"	Mis	L	Cav	Af	12
	3,400		Viola lime	Ord	D	Por		
			"Wilcox" Sand		S	Por		
			"Siliceous" lime	Cam-Ord	D	Por		
157			Lansing-Kansas City	Pen	L	Por	A	0
158	3,627		Lansing-Kansas City	Pen	L	Por	y	8
159			Bartlesville Sand	Pen	S	Por	ML	y
160			Oswego lime	Pen	L	Por		y
			Prue sand	Pen	S	Por		
161	3,445	25[4,6]	Basal conglomerate	Pen	S	Cav		0
162	3,375	32	Mississippi "chat"	Mis	L Cav	Cav		7
163	3,655	42	Mississippi "chat"	Mis	L	Cav		0
164	4,384	27	Mississippi lime	Mis	L	Cav	A	0
165			"Wiggins" sand	Pen	S	Por	ML	y
166			Bartlesville sand	Penn	S	Por	ML	y
167	3,280		"Siliceous" lime	Cam-Ord	D	Por		1
168			Layton sand	Pen	S	Por	A	y
			"Siliceous ' lime	Cam-Ord	D	Por		
169			Bartlesville sand	Pen	S	Por	A	y
			"Siliceous" lime	Cam-Ord	D	Por		
170			Bartlesville sand	Pen	S	Por	ML	y
			Mississippi lime	Mis	L	Cav		
171			y	y	y		y	y
172	3,600	32	"Oswald" lime	Pen	L	Por	A	2
173			Lansing-Kansas City	Pen	L	Por	D	y
174	3,398		Viola lime	Ord	D	Por	AM	
175								

TABLE 2.—*Summary of Drilling Operations in Kansas,* 1934
(Figures in body of tabulation represent number of holes.)

County	Completed during 1934							
	Dry and/or Near-dry Holes					Total	Productive Wells, Oil	Productive Wells, Gas
	Total Depths, ft.						(For Details, See Table 1)	
	Less than 1000	1000–2000	2000–3000	3000–4000	4000–5000			
Anderson	4					4	1	0
Barber					1	1	1	0
Barton			8			8	11	0
Butler		4	20			24	30	3
Chase						0	6	1
Chautauqua						0	3	1
Cherokee	2					2	0	0
Coffee		1				1	3	0
Cowley		2	3	4		9	9[1]	5
Crawford	4					4	8	0
Edwards					1	1	0	0
Elk		5	3			8[3]	19[2]	1
Ellis				1		1	5	0
Ellsworth				5		5	16	1
Finney				1		1	0	0
Franklin		1				1	0	0
Greenwood	1	17	13			31	37	0
Harper					1	1	0	0
Harvey				2		2	77[5]	2
Kingman				1	4	5	10	0
Labette	2					2	0	0
Lyon			1			1	0	0
Marion			2			2	3	0
McPherson		1	5	23		29	129[4]	2
Morris	1					1	0	3
Neosho	1					1	1	1
Osborne				1		1	0	0
Phillips				1		1	0	0
Reno				11	1	12	35[2]	0
Rice				30		30	92[1]	2
Rooks						0	3	0
Rush				2		2	1	3
Russell				11		11	50[3]	0
Sedgwick		1	6	12	2	21	44	0
Scott						0	1	0
Stafford			1	1	1	3	8	0
Sumner				2	3	5	2	0
Trego					2	2	2	0
Wabaunsee	1					1	0	0
Woodson	2	10				12	17	0
Total						246	624	24
Old oil wells deepened to new-oil production							60	
Old wells deepened and abandoned							5	
New completions							829	
Activity							894	

[1] Includes 1 old well deepened.
[2] Includes 4 old wells deepened.
[3] Includes 5 old wells deepened.
[4] Includes 14 old wells deepened.
[5] Includes 31 old wells deepened.

Pipe lines have been constructed or extended during the year to reach practically all fields except some recent discoveries, which are expected to secure market outlet during 1935, by the necessary building of new lines.

Acid treatment continues to be used throughout the state. Starting early in 1933, as a treatment to increase the production of old fields, producing from limestone, it rapidly became the practice to treat newly drilled wells in limestone horizons to increase their potential. This frequently permits the producer to secure a greater daily allowable, but practically forces all producers, of the same common source of supply, to treat new wells to remain on an equitable competitive basis. Acid-treated wells usually develop a much larger potential than natural pro-

TABLE 3.—*New Discoveries in Kansas*, 1934

(Fields arranged chronologically)

Line	Field	Location of Discovery Well	County	Discovery Date, 1934	Discovered by
1	Ritz[1]	NE. S.9-T.19-R.2W.	McPherson	Jan. 3	General Petroleum Co.
2	Churchill[1]	S.25-T.31-R.2E.	Sumner	Feb. 12	Derby Oil Co.
3	Russell	NW. SW. S.22-T.13-R.14W.	Russell	Feb. 12	Tom Palmer
3a		NE. S.28-T.13-R.14W.	Russell	Aug. 13	Joe Aylward
4	Bently[2]	C. NW. SW. S.19-T.25-R.1W.	Sedgwick	Mar. 7	Hartman et al.
5	Schulte	NW. SW. SE. S.6-T.28-R.1W.	Sedgwick	Mar. 18	D. R. Lauck et al.
6	Burrton[1,3]	C. SW. SE. S.26-T.23-R.4W.	Reno	Mar. 28	Sinclair
7	Hilger	SE. NW. S.16-T.26-R.4W.	Reno	Mar. 31	Stanolind-Amerada
8	Orth	SE. NE. NW. S.27-T.18-R.10W.	Rice	Apr. 2	Lario-Carter
9	Wilkins	SE. Cor. S.13-T.17-R.10W.	Ellsworth	Apr. 15	Smith and Ash
10	Dopita	C. SW. SW. S.31-T.8-R.17W.	Rooks	Apr. 20	Phillips Petroleum Co.
11	Dopita (deepened)		Rooks	Aug. 15	Alma Petroleum Co.
12	Wakeeney	C. SW. SW. S.11-T.11-R.23W.	Trego	May 15	R. B. McNeeley
13	Sharpe	NW. SE. S.18-T.20-R.9W.	Rice	May 7	Mid-Kansas
14	Geneseo	NW. SE. S.25-T.18-R.8W.	Rice	June 7	Continental Oil
15	Geneseo Townsite[4]	NW. SW. SW. S.1-T.18-R.8W.	Rice	Nov. 27	Yingling Bros.
16	Beyer	SE. SW. SE. S.16-T.19-R.9W.	Rice	June 20	National Refining Co.
17	Graber	NE. NW. S.32-T.21-R.1W.	McPherson	June 23	Continental Oil
18	Bolin	SE. SW. SE. S.36-T.26-R.6E.	Butler	July 18	Phillips Petroleum Co L. C. Hay
19	Otis	C. SW. S.10-T.18-R.16W.	Rush	July 18	Mid-Kansas
20	Grove	SE. NW. S21-T.19-R.9W.	Rice	July 18	Keith-Carter
21		SE. NW. S.21-T.19-R.9W.	Rice	Oct. 31	Keith-Carter
22	Whelan	C. NW. S.32-T.31-R.11W.	Barber	Aug. 2	Lario et al.
23	Straub	C. SE. NW. S.36-T.18-R.11W.	Barton	Aug. 11	Atlantic Oil Co.
24	Niedenthal	NE. S.23-T.14-R.15W.	Russell	Aug. 28	Lario et al.
25	Steinhoff	SE. C. S.21-T.29-R.6E.	Butler	Aug. 30	Pennwest Oil Co.
26	Hesston	NW. NE. NW. S.8-T.22-R.1W.	Harvey	Sept. 1	Hollow et al.
27	Stone	C. NW. NW. S.15-T.24-R.4W.	Reno	Sept. 24	Hartman et al.
28	De Moss	NE. NW. S.8-T.28-R.7E.	Butler	Oct. 9	Rex et al.
29	Fink[5]	SW. NW. NE. S.16-T.14-R.14W.	Russell	Oct. 17	H. H. Blair et al.
30	Lorraine	SW. NW. SW. S.13-T.17-R.9W.	Ellsworth	Nov. 19	Twin Drilling Co.
31	Lanterman	NW. SE. S.15-T.19-R.11W.	Barton	Dec. 6	Murfin et al.
32	Shallow Water	C. SE. NE. S.15-T.20-R.33W.	Scott	Dec. 8	Atlantic Oil Co.
33	Beaver	NW. SW. NE. S.16-T.16-R.12W.	Barton	Dec. 17	Darby Petroleum Co.
34	Sperling	SE. NE. NE. S.23-T.22-R.2W.	Harvey	Dec. 30	Broswood et al.
35	Ferguson[5,6]	SE. SW. S.21-T.30-R.8E.	Cowley	Dec. 31	Western Kansas Oil
36	Murphy	NW. NE. NE. S.7-T.35-R.3E.	Cowley	Dec. 31	S. A. Murphy

[1] This is a new horizon in an old field.

[2] Old dry hole plugged back and acid-treated.

[3] The Haury Field, Hunton Ls., has been combined with the Burrton Field, Hunton Ls., as the Burrton Field for proration purposes.

[4] Well being deepened at end of year. (Deepened to "Siliceous Ls" and abandoned Feb. 9, 1935.)

[5] Well being deepened at end of year.

[6] Completed as oil well, Jan. 4, 1935.

duction and show extremely rapid decline in most instances of large withdrawal. The general concensus of opinion is that acid treatment results in lower recovery costs per barrel by permitting withdrawal of total production within a shorter time. In many limestone areas, which have declined below economic operation, acid treatment permitted continuation of profitable production, which means that it has resulted

TABLE 3.—*(Continued)*

Line	Lease Name	Status of Field		Initial Production, Bbl.	Total Depth, Ft.	Producing Rock			Geologic Work Aiding in Discovery
		Wells Producing, End of 1934	Production in 1934, Bbl.[7]			Name	Age[a] as Used Locally	Character	
1	Middleswartz	1	*y*	275	2,399	Lansing	Pen	L	Core drilling
2	Ritz	1	1,082		1,613	Oread	Pen	L	Core drilling
3	Steinle	12	191,252	818	3,286	"Siliceous"	Cam-Ord	L	Surface
3*a*	Holland	2	24,116	560	3,204	"Oswald"	Pen	L	Core drilling
4	Jones	1	3,048	118	2,916	Kansas City-Lansing	Pen	L	Wildcat drilling
5	Jordan	1	25,613	1,174	3,652	Simpson	Ord	L	Core drilling
6	Base	33	329,450	1,489	3,597	Hunton	Sil-Dev	L	Core drilling
7	Hilger	2	47,122	968	4,067	Viola	Ord	L	Core drilling, seismograph
8	Habiger	1	*y*	Gas, 13,711,000	2,936	Kansas City-Lansing	Pen	L	
9	Wilkins	3	32,279	205	3,280	"Siliceous"	Cam-Ord	L	Core drill
10	Dopita	1	*y*	280	3,217	Kansas City-Lansing	Pen	L	Core drill
11		1		44	3,419	"Siliceous"	Cam-Ord	L	
12	Rhoades	2	No market outlet	882	3,604	Kansas City-Lansing	Pen	L	Surface
13	Proffit	1	*y*	Gas 2,753,000	2,288				
14	Lansing	3	59,154	1,294	3,127	"Siliceous"	Cam-Ord	L	Core drill
15	Maupin	1	525	60	3,245	Conglomerate	Pen		Wildcat drilling
16	Reese	1	*y*	Gas 8,000,000	1,979		Pen		Drilling in field
17	Graber	2	38,822	639	3,298	Hunton	Sil-Dev	L	Core drilling
18	Bolin	1	*y*	10	2,176				Surface
19	Mohr	1	4,009	153	3,526	Reagan	Cam	S3(?)	
20	Grove	7	76,802	215	2,985	Kansas City-Lansing	Pen	L	Subsurface
21				1,422	3,242	"Siliceous"	Cam-Ord	L	Subsurface
22	Whelan	1	6,307	75	4,426	Miss.	Mis	L	Magnetometer, surface
23	Straub	(shut in) 1	191	45	3,313	"Siliceous"	Cam-Ord	L	Seismograph
24	Neidenthal	(shut in) 3	0	705	3,250	"Siliceous"	Cam-Ord	L	Subsurface
25	Steinhoff	1	*y*	125	2,217	Kansas City-Lansing	Pen	L	Surface
26	Summerfield	2	3,354	247	3,356	Hunton	Sil-Dev	L	Wildcat drilling
27	Stone	1	9,739	523	3,386	Miss.	Mis	L	Core drilling
28	De Moss	1	*y*	35	2,731	Bartlesville	Pen		Sand Trend
29	Fink	(shut in) 1	976	192	3,154	"Oswald"	Pen	L	Surface, Subsurface
30	Rolph	1	628	526	3,205	"Siliceous"	Cam-Ord	L	Subsurface
31	Lanterman	1	*y*	199	3,355	"Siliceous"	Cam-Ord	L	Wildcat drilling
32	Vaniman	1	No market outlet	572	4,686	Miss.	Mis	L	Seismograph, torsion balance
33	Jarus	1	2,040	596	3,351	"Siliceous"	Cam-Ord	L	Seismograph, surface, subsurface
34	Sperling	1	*y*	1,624	3,345	Hunton	Sil-Dev	L	Subsurface
35	Ferguson	1		1,800,000 Gas	2,066	Kansas City-Lansing	Pen	L	Surface
36	Cadwell	1		78	3,504	Bartlesville	Pen	S	Core drilling

[7] Footnotes to column headings and explanation of symbols are on page 249.

in greater ultimate recovery per acre. Research work in connection with acid treatment is developing new and more effective methods of its application. Acid treatment has largely displaced the use of explosives in lime producing fields, but shooting is occasionally used and then followed by acid treatment with good results. Excessive and/or repeated acid treatment has been harmful to some wells by hastening or increasing the water.

Production costs vary considerably across the state because of the different types of production and different depths of wells. Some costs are reported as high as five dollars per barrel and others at a few cents. The low costs are due chiefly to producing gas with oil and marketing the gas, which is sold and charged as income to properties. Kansas oil-production costs are actually about one dollar per barrel, based on ordinary labor conditions and the usual investment in upkeep of properties. Reduced production costs are largely due to failure to spend money for the usual amount of labor and upkeep of producing properties, during the recent period of low prices. The increased drilling is bringing production costs to higher levels.

CONCLUSION

This should be considered as a progress report. The author will welcome corrective criticism from its readers in order that they may be passed on to the author of the 1935 production report for correction of that assembly.

It is impossible to assemble a complete and accurate report, especially on the older and unrecorded production of eastern Kansas fields.

Acknowledgments are due to the several geologists and others who have assisted in this report, and thanks are especially extended to the Messrs. Gail Carpenter, Forrest Winbish, Walter Larsh, Edward Koester and L. A. Crum for their helpful suggestions.

Oil and Gas Development in Kentucky

By Coleman D. Hunter* and Iley B. Browning†

(New York Meeting, February, 1935)

During the year 1934, Kentucky oil and gas operators have partly overcome their past depression fears and in the oil industry, with possibly more abandonments of old oil producers than the completion of new oil wells, produced 4,814,904 bbl. of oil in 1934 against 4,501,511 bbl. in 1933. In the gas industry of eastern Kentucky, 115 gas wells were completed during 1934. This production is delivered through two 20-in., one 16-in., one 12-in., one 10-in., and two 8-in. pipe lines to supply both domestic and industrial markets in Cincinnati, Ohio; Louisville, Lexington, Frankfort, Winchester, Ashland, Covington and other Kentucky towns; Washington, D.C., and other eastern cities.

The largest percentage of these gas wells and production are from the Devonian black shale area of Floyd, Pike, Knott, Martin and Magoffin counties, Kentucky.

In this area the largest percentage of 1889 wells, developing 421,215 acres, has been completed in the past 10 years, of which 55.3 per cent produce from the 400 to 550 ft. of Carbonaceous Devonian black shales.

The successful results obtained from these Devonian shales are due to the physical effects of the 5000 to 6000 lb. of gelatinated nitroglycerin with which the entire 400 to 550 ft. of shale is shot. A very small number of the shale wells are natural producers and do not require shooting.

Other than the Devonian shale gas production, the remaining 44.5 per cent of the gas in this field is encountered throughout the entire stratigraphic section above this horizon; namely, salt sands of Pennsylvanian age and Maxon, Big Lime and Weir of Mississippian Age. A very small percentage is encountered in the Corniferous Devonian lime and the Silurian Big 6 below the black shales.

In western Kentucky, in the counties of Henderson, Webster, Hopkins, McLean, Christian, Muhlenburg, Ohio, Daviess, Hancock, Breckenridge, Hart, Barren and Warren, many gas wells have been completed, but because of insufficient market, activity has been somewhat desultory. The area is served by the pipe lines of the Kentucky Natural Gas Corporation, with headquarters at Owensboro. Their market is increasing and the gas is delivered to Owensboro, Henderson, Madisonville, and many

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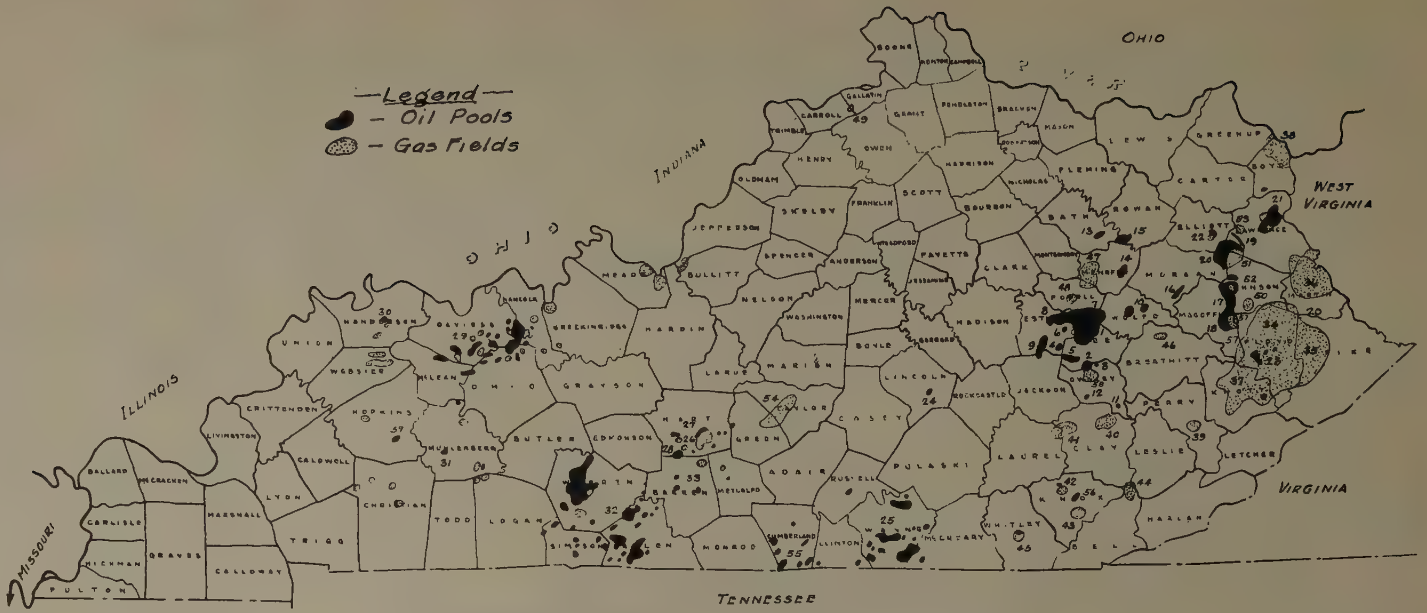

FIG. 1.—LOCATION OF OIL AND GAS POOLS IN KENTUCKY.

Oil Pools

1. Big Sinking.
2. Ida May.
3. Pebworth.
4. Ross Creek.
5. Goosey Creek.
6. Trabue.
7. Ashley.
8. Irvine Cow Creek—Fitchburg.
9. Wagesville.
10. Compton and Stillwater.
11. Buffalo Creek.
12. Island Creek.
13. Olympia.
14. Menefee.
15. Ragland.
16. Cannel City.
17. Oil Springs.
18. Burning Fork.
19. Blaine and Rt. Fork.
20. Elna.
21. Lawrence Co.
22. Isonville.
23. Beaver.
24. McKinney.
25. Wayne.
26. Logsden Valley.
27. Bonnieville.
28. Le Grande.
29. Owensboro.
30. Henderson.
31. Muhlenberg.
32. Bowling Green.
33. Barren Co.
55. Cumberland Clinton.
56. Little Richland field.
59. Morton's Gap.

Gas Fields

34. Floyd County.
35. Pike County.
36. Martin County.
37. Knott County.
38. Ashland.
39. Hazard.
40. Oneida.
41. Burning Springs.
42. Indian Creek.
43. Artemus.
44. Red Bird.
46. Big Six.
47. Menefee.
48. Powell County.
49. Carlisle.
50. Swamp Branch.
51. Flat Gap.
52. Win.
53. Cain Creek.
54. Green Taylor.
57. Ivyton, Licking River, Mine Fork.
58. Needmore.

Oil and Gas Field

45. Williamsburg.

TABLE 1.—*Oil and Gas Production in State of Kentucky*

Line Number	Field, *County*	Age, Years to End of 1934
1	Big Sinking, *Lee, Estill, Powell, Wolfe*	17[1]
2	Ida May, *Lee*	10
3	Pebworth, *Owsley*	11
4	Ross Creek, *Estill*	17
5	Goocey, *Lee*	14
6	Trabue Heirs, *Lee*	5
7	Ashley, *Powell*	17
8	Irvin-Cow Creek-Fitchburg, *Estill, Powell*	19
9	Wagersville, *Estill*	18
10	Campton and Stillwater, *Wolfe*	22
11	Buffalo Creek, *Owsley*	11
12	Island Creek, *Owsley*	8
13	Olympia, *Bath*	17
14	Menifee, *Menifee*	15
15	Ragland, *Bath, Rowan*	34
16	Cannel City, *Morgan*	22
17	Oil Springs, *Johnson, Magoffin*	15
18	Burning Fork, *Magoffin*	12
19	Blaine, *Lawrence, Johnson*	16
20	Elna, *Johnson*	14
21	Louisa, *Lawrence*	22
22	Ambrose-Weller, *Ohio*	9
23	Isonville, *Elliott*	18
24	Beaver Creek, *Floyd, Knott*	19
25	McKinney, *Lincoln*	15
26	Wayne County, *Wayne, McCreary*	37
27	Logsdon Valley, *Hart*	5
28	Bonnieville, *Hart*	2
29	Le Grande, *Hart*	5
30	Owensboro, *Daviess, Ohio, McLean, Hancock, Breckinridge*	16
31	Henderson, *Henderson*	4
32	Muhlenberg, *Muhlenberg*	5
33	Bowling Green, *Allen, Warren, Simpson*	16
34	Barren, *Barren*	16
35	Floyd Gas, *Floyd*	30
36	Pike Co. Gas, *Pike*	4
37	Martin Gas, *Martin*	37
38	Knott County, *Knott*	29
39	Ashland, *Boyd*	11
40	Perry Gas (Hazard), *Perry*	4
41	Oneida, Burning Springs, *Clay*	9
42	Burning Springs (Gas), *Clay*	35
43	Indian Creek Gas, *Knox*	5
44	Artemus Himyar Gas, *Knox*	4
45	Red Bird Gas, *Bell*	4
46	Williamsburg Oil and Gas, *Whitley*	32
47	Big 6 Gas, *Breathitt*	15
48	Rothwell Gas, *Menifee*	33
49	Powell Gas, *Powell*	3
50	Carlisle Gas, *Gallatin, Carroll*	4
51	Swamp Branch Gas, *Johnson*	7
52	Flat Gap Gas, *Johnson*	15
53	Win Gas, *Johnson*	17
54	Cain, *Lawrence*	5
55	Green Taylor Gas, *Green, Taylor*	15
56	Cumberland, Clinton, *Cumberland, Clinton*	40
57	Little Richland, *Knox*	32
58	Ivyton, Licking, Mine Fork Gas, *Magoffin*	15
59	Needmore Gas, *Owsley*	14
60	Morton Gap, *Hopkins*	12
61	Buford, *Ohio*	5
62	Habit, *Daviess*	4
63	Lindsay Taylor, *Daviess*	5
64	Herbert, *Ohio, Hancock*	14
65	Hayden, *Daviess*	7

For footnotes see pages 317 to 319.

TABLE 1.—(*Continued*)

Line Number	Area Proved, Acres				Total Oil Production, Bbl.				Average Oil Production, Bbl.		
	Oil	Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov. 1934	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934
1	13,957	0	0	13,957	35,327,890	630,347	642,259	1,760	2,531		7/10
2	321	0	0	321	463,555	11,360	10,950	38	1,444		6/10
3	60	0	0	60	63,444	2,036	1,633	4	1,058		3/10
4	468	0	0	468	727,883	6,203	10,510	29	1,555		7/10
5	0	0	0		73,684	1,977	1,505	4			4/10
6	0	0	0		77,839	13,007	11,600	32			2 3/10
7	1,091	0	0	1,091	2,827,502	39,268	57,508	158	2,592		3/10
8	4,637	0	0	4,637	11,593,792	169,056	159,301	436	2,500		4/10
9	400	0	0	400	377,600	4,516	5,542	15	944		6/10
10	1,447	0	0	1,447	625,767[2]	4,000	4,435	15	435		2/10
11	10	0	0	10	20,000	400	2,000	35	2,000		7
12	0	20	0	20	9,899				499		
13	0	0	0	0	1,706						
14	0	0	0	0	231,832						
15	0	0	0	0	258,930[3]						
16	600	0	0	600	376,140	1,918	1,962	5	625		3/10
17	6,100	0	0	6,100	8,376,804	229,423	220,088	553	1,373		53/100
18	918	0	1,895	2,813	1,529,810	69,933	74,128	190	1,666		1 2/10
19	6,820	0	0	6,820	13,611,997	608,367	521,666	1,400	1,996		1 25/100
20	0	0	0	0	1,426,086	48,810	48,841				
21	1,*xxx*	0	600	2,*xxx*	1,421,556	40,980	40,528	111	1,*xxx*		1/10
22	600	0	0	600	3,120,000	180,000	120,000	316	5,200		1 6/10
23	100	46	2,000	2,146	75,357	3,886	3,378	9	754		4/10
24	115	0	0	115	140,754	5,800[5]	4,600	14	1,407		7
25	0	0	0	0	4,502						
26	8,544	0	0	8,544	4,293,757[4]	29,633	36,335	100	503		1/10
27	885	0	1,000	1,885	1,507,307	430,693	320,659	450	1,703		2
28	0	0	0	0	108,949	48,949	60,000	164			
29	1,643	0	0	1,643	3,725,251	249,009	133,341	365	2,267		
30	9,626	0	0	9,626	19,784,889	1,479,248	2,073,036	7,423	2,056		2 7/10
31	218	0	0	218	353,217	81,201	59,321	163	1,620		2 6/10
32	0	0	0	0	196,972	21,972	35,858	98			4 9/10
33	10,356	0	0	10,356	11,632,451	243,277	233,738	611			3/10
34	3,667	0	0	3,667	2,305,613	32,442	46,705	128	629		
35	0	0	205,075	205,075							
36			50,000	50,000							
37			69,300	69,300							
38	50	50	90,000	90,100							
39			16,640	16,640							
40			1,200	1,200							
41			7,000	7,000							
42											
43			1,200	1,200							
44			4,600 EW								
			5,000	5,000							
45			600	600							
46		700		700	4,000			[39]			
47			1,200	1,200							
48			15,360	15,360							
49											
50											
51	3		3,000	3,003	Not Marketed						
52			10,880	10,880							
53			1,980	1,980							
54			550	550							
55											
56					2,*xxx*,*xxx*[27]						
57											
58			6,840	6,840							
59			6,400	6,400							
60	50			50	[28]						
61	346			346	1,000,000	200,000	150,000	416	3,000		3 3/10
62	100			100		60,000					
63	15			15	21,300	1,600	1,200	3 5/10	1,420		1 2/10
64	350			350	370,000	39,000	20,000	54	1,057		4/10
65	300			300	328,000	30,000	24,000	66	1,090	109	1 8/10

For footnotes see pages 317 to 319.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								Average Depth, Ft.	
						During 1934		At End of 1934						
	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone
1					2,384	2x	1xx[8]	0	2,384			2,198	700–1,200	650–1,150
2					82				82			65	1,000–1,200	
3					15				15			15	1,000–1,200	975–1,175
4					180				180			40	550– 900	520– 870
5					13		2		13			11	900–1,100	985–1,070
6					15	1			15			15	940–1,140	900–1,100
7					523				523			458	600–1,000	550– 950
8					1,110				1,024			1,024	120–1,000	85– 960
9					100				100			27	100– 400	75– 375
10					275		6x		275			67	1,150–1,300	1,125–1,375
11					7			3	4			4	1,125	1,110
12					6			2					750±	700±
13					20									
14					150								1,040–1,250	1,020–1,230
15					100				100				650– 850	625– 825
16					75				75			19	1,800–2,000	1,780–1,980
17					1,055		10		1,033			1,033	900–1,260	860–1,220
18					159				159			159	1,080–1,400	1,040–1,360
19					1,118				1,118			1,118	760–1,060	700–1,000
20					250				250			230	640–1,100	600–1,060
21	[6]				286			6	286		6	240	1,600–1,900	1,575–1,875
22					190				190			190	725	650– 700
23	y	y	y	y	39			1	25	4	10	38	875–1,500[9]	825–1,350
24					35		3	7	35			2	1,000–1,500	950–1,475
25					8				4		4		121– 360	101– 390
26					1,451				1,451			820	400– 700	385– 680
27					25x				225		2x	25x	800–1,100	780–1,075
28													700– 850	
29					45x				393		6x	45x	700– 850	
30					2,874				2,874			2,800	600–1,300	
31					63				63			63	650–1,650	625–1,630
32					20				20			20	1,250–1,700	
33					2,026				2,026			1,924	270– 700	265– 785
34					791								200–1,300	
35	y	y[7]	y	y	1,076	45	2x	4 Mo. of yr.			1,076	1,0xx	[10]	
36	y	y[34]	y	y	134			2x			134	1xx	[58]	
37	y	y[35]	y	y	197			1x			197	17x	[46]	
38	y	y	y[44]	y	140	32	3	4 Mo.	1		139	136	[47]	
39	y	y	y		216		3x		2		214	1xx	2,200±	1,650±
40	y	y[36]	y	y	6			2			6	4	2,700–3,300	2,200–2,900
41	y		y		24			20			4	4	1,550–1,700	1,525–1,675
42	[37]				5						5			
43	y	y[38]	y		6							6	1,550	1,500
44	y	y[39]	y		18			11			18	7	1,110± 2,100±	1,018± 2,000± [48]
45	[30]				3			3			3		3,500±	3,400±
46					30				25		5	5	Oil-- 900± Gas-1,750±	850± 1,700±
47	y[31]	y	y		10						10	6	1,750 to 1,900	1,725 to 1,875
48	y	[40]			8x								550– 700	500– 650
49		[41]			2x						2x			
50											17		240– 350	225– 335
51		[42]			22			22	2	1	19		1,800	1,425
52	y	y	y	y	2xx			1xx[45]				1xx	780–1,200	740–1,160
53	y[32]	y	y	y	28								700–1,100 2,100–2,500	670–1,070 2,050–2,450
54					9			9		9		9	1,670–1,760	1,650–1,740
55	[33]				1xx					1xx			390– 700	370– 680
56														
57													200– 500	
58	y	y[43]	y	y	104		2				104	8x		
59				y	48						48		900–1,200	850–1,150
60					5				5				Penn. 420–575 Miss. 2,060±	
61					125	4	1		129			129	600	585
62	y′				10	1	1		10		2	12	930	910
63					3				3			3	1,125	1,085
64					130				130			130	500 & 75 0	Jett-450–500 Barlowe 735–750
65					45		8		37			37	1,020	1,005

For footnotes see pages 317 to 319.

TABLE 1.—*(Continued)*

Line Number	Oil Production Methods at End of 1934			Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1934					Character of Gas Approx. Average during 1934		Producing Rock
	Number of Wells		Injection into Reservoir[d]	Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name
	Flowing	Pumping			1933	1934	Maximum	Minimum	Weighted Average					
1	0	2,198					42	37	40		P			Corniferous
2		65									P			Corniferous
3		15												Corniferous
4		40									P			Corniferous
5		11												Corniferous
6		15					42	40	41		P			Corniferous
7		458												Corniferous
8		1,024												Corniferous
9		27									P			Corniferous
10		67												Corniferous
11	2	2	Acid[11]			210	42.8	40.8	41.8	0	P			Big Lime
12									39		P			Big Lime
13														
14														Corniferous
15														Corniferous
16		19												Corniferous
17		1,033	5	180	300	300	38	34	36.5		P			Weir
18		159					38	36	36.5		P			Weir
19		1,118	55	550	y	385	38	34	36.5		P			Weir
20		230					38	34	36.5		P			Weir Berea
21		240					40	37	38.5		P			Berea
22		190					36.2[12]		36.2[12]					Jett sand
23		25		450					[13]	1 7/100	P	[14]		Weir, Br. shale, Cornif.
24	1	1									P			Maxon, Big Lime[15]
25														Corniferous
26		820												Beaver
27		225												(Blue sand)
28														(Blue sand)
29		393												Blue sand
30		2,800												Pottsville, Fugua, Stray, Jett, Jones, Jackson, Barlow, Bethel
31		63												Triplett-Jones
32		20												Big Lime
33		1,924												Shallow sand Corniferous Deep sand
34														Amber Oil S, Cornif. 2nd Sand, Trenton
35				Shale 550#								1,150		Big Injun, Berea, Black Shale, Salt sand, Maxon, Big Lime, Cornif.
36												1,150	2	Salt sand, Maxon, Big Lime, Brown shale
37												1,150		Salt sand, Maxon, Black shale, Big Lime
38												1,150		Salt sand, Maxon, Big Lime, Big Injun, Brown shale
39				y	y	y								Salt Sand, Maxon, Black shale, Gordon[55] Cornif.
40														Salt sand, Big Lime, Brown shale
41				305										Corniferous
42														Corniferous
43				See Pet. Ex.										Big Lime

For footnotes see pages 317 to 319.

other smaller Kentucky towns and northward in the western part of Indiana, including Evansville and Terre Haute.

The authors found it hard to present as individual fields this gas development, as the individual pools are comparatively small and scattered over a wide area in the counties named. Production is from the Pennsylvanian and all the Chester sands, and in Hart, Barren, and Warren counties from the Devonian shale and the Louisville limestone.

Throughout western and eastern Kentucky probably as many as 250 or more wildcat wells were completed. Some extensions of old fields were discovered, and in Ohio county, in the Fordsville area, three very profitable and prolific pools were developed. Each pool discovered was from 200 to 300 acres in extent. The depth of the wells is about 400 ft. to the Jett sand, the producing formation. The initial production per well was from 10 to 200 bbl., with the larger number starting at about 100 bbl. per day.

In the oil industry of eastern Kentucky, operators are encouraged by refiners to wildcat for new production to meet the depletion of old.

TABLE 1.—(*Continued*)

Line Number	Oil Production Methods at End of 1934			Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1934					Character of Gas Approx. Average during 1934		Producing Rock
	Number of Wells				Average at End of		Gravity A.P.I. at 60° F.							
	Flowing	Pumping	Injection into Reservoir[d]	Initial	1933	1934	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft	Gal. Gasoline per M. Cu. Ft.	Name
44				310±	310± [49]	310±						1,180	Nil	Maxon—Brown shale Corniferous
45														Big Lime B. shale Cornif.
46				240			[50]				P			Salt sand Big Lime
47														Big 6
48														"Cornif." Ragland sand
49														Corniferous
50				160		20								Trenton
51														Maxon, Big Lime, shale
52														Weir, Corniferous[56]
53														Weir, Big 6
54												[53]		Corniferous
55														
56														Sunnybrook-Trenton
57														Salt sand
58													[54]	Weir, Black shale, Cornif., Salt sand, Maxon, Big Lime, Injun
59				317								1,085	1 qt.	Corniferous
60														Salt sand-Caseyville
61		129					36		36					Pottsville
62		10					35		35					Fugua Stray sand
63		3												Jones (Hardingsbury SS)
64		130					35.8[51]	33	34.4		P			Jett, Barlowe
65		37					34[52]		34					Jett

For footnotes see pages 317 to 319.

TABLE 1.—(*Continued*)

Line Number	Producing Rock				Structure[j]	Number of Dry and/or Near-Dry Holes to End of 1934	Deepest Zone Tested to End of 1934		Reference to Text[k]
	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.			Name	Depth of Hole, Ft.	
1	Dev	LS	Por	30	MC[18]	3*xx*	Trenton	2,*xxx*	23
2	Dev	LS	Por	20	MC	3*x*	Devonian		
3	Dev	LS	Por	20±	MC	1*x*	Devonian		
4	Dev	LS	Por	20	T	3*x*	Ordovician		
5	Dev	LS	Por	20±	MC	5*x*	Devonian		
6	Dev	LS	Por	20	MC				
7	Dev	LS	Por	40	AF	4*x*			
8	Dev	LS	Por	40±	AF	1*xx*	Ordovician		
9	Dev	LS	Por	25±	AF	7*x*	Ordovician		
10	Dev	LS	Por	25±	AD	8*x*	Devonian	2,190	
11	Miss	LS	Por	15	A	3	Devonian	1,962	Jillson[66]
12	Miss	L	Cav	50±	MC[19]	10	Devonian		
13	Sil	L	Cav	10±	MC	7*x*	Ordovician		
14	Dev	LS	Por	20±	MC	4*x*	Ordovician		
15	Dev	LS	Por	25±	SC	1*xx*	Ordovician		
16	Dev	L	Por	20±	AF	2*x*	Devonian		
17	Miss	S	Por	35	DA	9*x*	Trenton LS	3,815	
18	Miss	Sand	Por	30	Dome	4*x*	Trenton LS	3,900	
19	Miss	Sand	Por	60	Dome	1*xx*	Devonian		
20	Miss	S	Por	30	DF A S	15*x*	Devonian		
21	Miss	S	Por	20±	S	1*x*	Ordovician	4,975	
22	Miss	S	Por 20	12–75	AN[20]	56	Trenton	4,020[24]	
23	Miss, Dev	S H LS	Por	40± 350± 20±	A	8	Devonian	1,780[25]	
24	Miss	S-L	Por-Cav	15±	T[21] ML MC	2*x*[15]	Ordovician	3,706	
25	Dev	LS	Por	18±	MC	4	Ordovician	855	26
26	Miss	LS	Por	12	S		Ordovician	1,921	26
27	Sil[16]	L	Cav	15±	MC[22] A	4*x*	Ordovician		16
28	Sil	L	Cav	15±	MC		Silurian		
29	Sil	L	Cav	10±	T MC	1*xx*	Silurian		
30	Penn Miss	S	Por 18 to 20	2 to 75	AN ATD	1,*xxx*	Ordovician		
31	Penn Miss	S	Por	30±	DA	6*x*	Devonian		
32	Miss	LS	Por	20±	D	2*x*	Devonian		
33	Miss Dev S	LS LS	Por	15±	MC DTA	1,*xxx*	Ordovician		
34	Miss, Dev Sil, Ord	LS	Por	10±	MC TND	1,*xxx*	Ordovician		
35	Penn, Miss, Dev	S L H	Por Cav	20 to 500[17]	A D MC T N S	93	Devonian	3,628	
36	Penn, Miss, Dev	S, L, H	Por Cav	10–800[58]	AAM[61] HMU MCDTS	36[65]	Devonian	4,181	
37	Penn, Miss, Dev	S, L, H	Por Cav	[46]	A[62] AFDT MCS	33	Devonian		
38	Penn, Miss, Dev	S, L, H	Por Cav	20–500[44]	AAM HMCD TS	19	Ordovician	3,706	
39	Penn, Miss, Dev	S, H, SL	Por	50± 400±	T	29	Ordovician	4,669	66
40	Penn, Miss, Dev	S, L, H	Por Cav	150± 50± 500±	MC	11	Devonian	3,637	
41	Dev	LS	Por	20±	A MC	15	Devonian	2,284	

For footnotes see pages 317 to 319.

During 1934 some 40 to 50 new wells were drilled in the vicinity of Ida May in Lee County. Approximately 50 per cent were commercial producers from the Corniferous limestone, and at this time five wells are being drilled.

During the year over 12 muriatic acid treatments have been made on oil wells producing from limestone in eastern Kentucky. Nine or more treatments were made in Corniferous lime producers, but no appreciable results were obtained. In the Buffalo, Owsley County, pool, which produces from a locally sandy phase in the Mississippian Chester limestone, three wells were treated during the summer of 1934 by William E. Snee, of West Elizabeth, Pa. The production from these three wells was increased from 6 to 28 bbl. per day after a 50-day test.

In the past three months intensive studies relative to repressuring and flooding have been made by leading engineers and geologists in the state. Prompt cooperation has been given by both members of the Kentucky Oil and Gas Association and the Geological Department of the State Department of Mines and Minerals. Experimental laboratories are

TABLE 1.—(*Continued*)

Line Number	Producing Rock				Structure[j]	Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934		Reference to Text[k]
	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.			Name	Depth of Hole, Ft.	
42	Dev	LS	Por	25±	AD	1x	Devonian		
43	Miss	L	Cav[38]	20	T	1	Mississippian	1,552	
44	Miss, Dev	S, H, LS	Por	30±	A	2	Devonian	2,225	
				175±	AF				
				100±	D				
45	Miss, Dev	L, H	Cav	100±	MC[63]	2	Devonian	3,725	
			Por	175±					
				50±					
46	Penn, Miss	S, L	Por	Oil-30±	A	1x	Ordovician	3,350	66
			Cav	Gas-20±					
47	Sil	S	Por	25±	A	1x	Silurian		
48	Dev	LS	Por	40±	D	4x	Ordovician		
49	Dev	LS	Por	20±	MC	1x			
50	Ord	LS	Por	15±	D	1x	Ordovician	967	
51	Miss, Dev	S, L, H	Por	40±	Depositional		Devonian	1,816	
			Cav	350±					
52	Miss, Dev	S, LS	Por	40±	D	2x	Ordovician	3,719	
53	Miss, Sil	S, LS	Por	30±	A	8	Devonian		
54	Dev	LS	Por	18	MC	7	Devonian	1,983	
55	Ord	LS	Por	20±					
56	Ord	S, LS	Por		AD		Cambro-Ord.	1,934	
57	Penn	S	Por	15±	A				
58	Penn, Miss, Dev	S, H, L	Por	40±[59]	DA	57	Ordovician	3,950	
			Cav	450±	MC				
					TS				
59	Dev	LS	Por	40±	MC	25	Devonian		
60	Penn, Miss	S, L	Por	20±	AF		Mississippian	2,132	
				6±					
61	Penn	S	Por[57]	15	Channel	84	Mississippian	1,250	24
			Por						
62	Miss	S	18–20	20	A	10	Mississippian	1,350	24
63	Miss	S	Por	40	AF[64]	13	Mississippian	1,340	24
64	Miss	S, LS	Por	5–50[60]	T	35	Mississippian	950	24
					A				
65	Miss	S	Por	2–22	AN	19	Mississippian	1,020	24
			18						

For footnotes see pages 317 to 319.

[a] Footnotes to column heads and explanation of symbols on page 249.

[1] Age from first oil run.

[2] Production from 1910 to date only.

[3] Production from 1916 to exhaustion.

[4] Production from 1910 to end of 1934, inclusive.

[5] The old oil lines serving this section were abandoned in 1928. Oil production when encountered by gas developing companies is either shut in or, if close to the railroad, shipped by rail.

[6] Gas production small, not commercialized. Production from Berea, Devonian shale and Corniferous lime

[7]

	Sands	Percentage of Total Number Producing Wells, by Horizons	Average Rock, Lb.
Penn.	Salt sand	8.5	250
Miss.	Maxon	12.7	275 to 400
Miss.	Big Lime, Injun	6.4	150 to 400
Dev.	Black shale	63.5	400 to 550
Dev. Miss.	Miscellaneous	1.0	300 to 600
All	Dry	7.9	0

[8] Salvaging wells in the Big Sinking pool has become a very profitable business during 1934. Over 100 wells have been pulled and during 1935 the abandoned wells will possibly exceed 1934.

[9] "Weir Sand," "Miss.," 875 to 910, produces oil and gas; Brown shale, "Dev.," 1050 to 1400, produces gas only; Corniferous, "Dev.," 1425 to 1575, produces gas only. Small shows of oil and gas noncommercial encountered "Berea," "Miss."

[10]

		Bottom	Top
Penn.	salt sand (three)	800–1100	750–1050
Miss.	Maxon	1000–1400	950–1350
Miss.	Big Lime	1300–1800	1200–1700
Miss.	Big Injun	1500–2000	1460–1960
Miss.	Berea	2000–2800	1950–2750
Dev.	Black shale	2300–3500	1800–3000
Dev.	Cornif.	2800–4000	2500–3500

[11] The Buffalo oil pool was commercially developed in 1923–1924 when 10 wells were completed in Sandy lime and sandy oolitic horizon in the Chester Mississippian. To 1928 this property delivered 16,081 bbl. of oil and during 1928 lost the market because the 4-in. oil line was sold to a gas-transportation company. During 1934 five wells were cleaned out, reconditioned and three were treated with acid. The first well treated was flowing once or twice a week from 2 to 4 bbl. During the first 50 days after treatment this well produced 1182 bbl., or more than the entire property produced at flush production. This is the only area in Eastern Kentucky known to the writers where acid treatments have been entirely successful.

[12] Gravity, 36.2°; B. S. & W., trace; distillate: gravity, 37.7°; per cent, 10.0; color, prime white.

[13] Specific gravity, 0.85555, equivalent to 33.6° Bé. Distillate below 150° C. (302° F.); 15.4 per cent gasoline fraction. Distillate 150° to 300° C. (302–572° F.) 31.2 per cent burning-oil fraction; thick brown tar, 53.4 per cent.

[14] B.t.u. and gallons of gasoline per 1000 cu. ft. indefinite owing to leaking packers, etc. Gas from three horizons not separated.

Other than the dry holes drilled in the Isonville oil and gas field, some 35 or 40 dry or nearly dry holes have been drilled over Elliott County. Elliott County, Kentucky, is a structural paradise, being traversed from west to east by Sandy Hook anticline, on which are located the Sandy Hook and Burke dome with closures of 50 and 100 ft., and being flanked on north by the Little Sandy fault with a displacement of 65 ft. From south to north the Paint Creek anticline crosses the Sandy Hook anticline, forming Burke dome at point intersection. Of intensive interest in northeastern Elliott Creek on waters of Little Fork of Sandy River are igneous dikes, which have been a great promotion source and are known locally as the Diamond Mines. These dikes were prospected extensively during 1900 to 1905, for precious stones.

[15] From over 2000 holes penetrating the Maxon sand and Big Lime, only 35 wells produced oil of any commercial value. Oil when encountered in the Big Lime produces large amounts for a very short time, suggestive of creviced condition; while Maxon oil is produced from a brown to light, coarse sand with much longer life.

[16] Dr. William L. Russel [Oil and Gas Pools of Hart County, Ky., Kentucky Geol. Survey *Bull.* 5 [7].] correlates the Blue sand (Corniferous) in this pool as Silurian in age; while to the north, because of the Northwest dip, the Devonian shale rests on progressively younger rocks, possibly Devonian limestone.

[17]

Thickness	
50 to 100	Sand
20 to 110	Sand
100 to 240	Lime Cav
20 to 60	SL
30 to 75	S. shells
475 to 560	Shale
500 pays top or bottom	

[18] D. J. Jones and A. C. McFarlan [Geology of the Big Sinking Pool of Lee County, Ky. Bur. Mineral and Topographic Survey, University of Kentucky (1933)] have most efficiently discussed deposition, stratigraphy, structure and deformation, reservoir, source rocks, development of reservoirs and factors governing accumulation for this area.

W. R. Jillson: Kentucky Geol. Survey (1921) **2** [VI], 149–153.

D. J. Jones and A. C. McFarlan: Reference of footnote 18.

W. V. Howard: *Bull.* Amer. Assn. Petr. Geol. (1928) **12**, 1153–1161.

[19] Production controlled by crevices in the oolitic limestone and not related to structural conditions.

[20] Production throughout field is independent of structures, sand conditions being the controlling factor.

[21] Although oil production is encountered on structures as before mentioned, the writer believes that oil production is controlled by depositional conditions within the horizon more than by structural conditions of same.

[22] Although most of the oil production has been found on closed anticlines in areas where the formation contains no salt water and structure has little or no influence on determining the locations of the production, which depends on the occurrences of porous and permeable limes in the otherwise impermeable rock (Dr. Russel).

[23] E. W. Shaw: The Irvin Oil Field, Estill County, Kentucky. U. S. Geol. Survey *Bull.* 661-D (1917).

[24] N. W. Shiarella: Typical Oil-producing Structures in Owensboro Field in Western Kentucky. Kentucky Geol. Survey *Bull.* 3 [5] (1930).

[25] Economic Papers on Kentucky Geology. Kentucky Geol. Survey (1921) [6].

[26] W. R. Jillson: Kentucky Geol. Survey (1922) [6].

[27] Cumberland and Clinton counties have produced over two million barrels of oil, but as oil has been shipped by water, truck, pipe line and railroad for over forty years, production figures are impossible. The old American well was drilled in Cumberland County over ninety years ago, and oil from same was used for medicinal purposes in this county and Europe.

[28] Production 4,902 bbl. Sept. to Dec., 1923 inclusive; 12,912 bbl. in 1924; 10,524 bbl. in 1925.

[29] Oil production is from the Pennsylvanian salt sands, and in all this small pool has never exceeded 175 bbl. per month. From August, 1919, to September, 1922, only 3278 bbl. of oil was run.

Several of these oil wells were deepened to Miss. Big Lime, where large open flows of gas were encountered. Some wells are reported as large as 3,500,000 cu. ft. open flow, and original pressures of 240 lb. This production is utilized domestically in the town of Williamsburg.

[30] No market for developed gas.

[31] Gas from this field is delivered to transmission line nine miles to north in Morgan County. Production is near depletion at this time.

[32] This field is practically depleted.

[33] Gas from this field has been used for local domestic purposes and for the manufacturing of carbon black. All carbon manufacturing has been discontinued.

[34]

	Sands	Percentage of Total Number Producing Wells, by Horizon
Penn.	Salt sand	1.2
Miss.	Maxon	7.6
Miss.	Big Lime, Injun	5.3
Dev.	Black shale	64.7
All	Dry	21.2

[35]

	Sands	Percentage of Total Number Wells Producing, by Horizon
Penn.	Salt sand	16.1
Miss.	Maxon	23.9
Miss.	Big Lime, Injun	16.0
Dev.	Black shale	29.1
	Miscellaneous	0.6
	Dry	14.3

[36] Production furnishes town of Hazard domestic.

[37] Gas production from this field is only utilized locally for domestic purposes.

[38] Although five of the producing gas wells are on the Indian Creek dome, which has only a small closure, the authors believe that production is controlled entirely by accumulation in creviced limestone, with no direct relation to structures.

[39] During 1931–1932 eighteen gas wells were drilled in the Artemus Himyar field of Knox County, Ky., developing 15,000,000 cu. ft. of open flow.

[40] Menifee gas field exhausted now being used for gas storage field.

[41] Gas production from this field is utilized domestically in small town of Stanton and as fuel to pump oil wells in Lee County.

[42] During 1927—28 wells were completed, reported as developing 3,511,000 cu. ft. of gas from 20 wells and 6 barrels of oil from two wells. Other than local use no market has as yet been obtained.

[43]

	Sands	Percentage of Total Number Wells Producing, by Horizon
Penn.	Salt sand	19.9
Miss.	Maxon	5.6
Miss.	Big Lime, Injun	4.2
Miss.	Weir	23.0
Dev.	Black shale	9.9
Dev.	Cornif.	2.0
All	Dry	35.4

Large percentage of dry holes due to extensive wildcatting for oil and gas in vicinity of Weir oil and gas fields.

[44]

	Sands	Percentage of Total Number Producing Wells, by Horizon
Penn.	Salt sands	3.1
Miss.	Maxon	8.2
Miss.	Big Lime, Injun	6.8
Dev.	Black shale	68.6
Dev. Miss.	Miscellaneous	1.4
All	Dry	11.9

[45] This Weir gas field is near completion.

[46] Similar to Floyd County.

[47] Similar to Floyd County, but slightly deeper because of higher topographic elevations. Relief variations 600 to 1500 feet.

[48] Producing horizons in this pool are Maxon from 1080 to 1110±, brown shale from 1780 to 1950± and Corniferous lime from 1960 to 2100±.

[49] Of intensive interest in this field is the fact that the rock pressure of all sands both shallow and deep is around 300 lb. The only explanation the authors can reasonably assume is the fact that the Artemus anticline south of gas field is traversed by a fault. This, with other disturbances caused by the Pine Mountain overthrust fault 15 miles to the southeast, have permitted the pressures of the various horizons to equalize.

[50] Distilled below 150° C. (302° F.) gasoline fraction is 16.3 per cent; distilled 150° to 300° C. (302°–572° F.), kerosene fraction is 32.6 per cent; green-brown tar, 49.8; water, 0.4; loss, 0.7.

[51] Gravity, 35.8°; color, dark brown, thin; distillate below 150° C. (302° F.), 18.9 per cent; distillate 150° to 300° C. (302°–572° F.), 31.0 per cent; thick brown tar, 49 7 per cent; lost in analysis, 0.4 per cent. Gasoline fraction, burning-oil fraction. Began to distill at 60° C. (140° F.).

[52] Gravity, 34.0°; B. S. & W., trace.

[53] Gas from the Corniferous in this field is so impregnated with SO_2 that it is noncommercial at this date.

[54] Gas from the Weir gas fields is higher in gasoline per 1000 cu. ft. than gas from any other horizon in eastern Kentucky.

[55] In the Ashland gas field the Gordon sand appears in lenticular bodies in the Devonian shale producing wells of large open flow, but at no other place in Kentucky does this sand appear.

being opened by the State Geological Division and actual experiments will be made during 1935 in some of the nearly depleted oil pools. Probably the next few years will see much activity by the industry in applying the various methods of increasing production from old wells throughout the state.

ACKNOWLEDGMENTS

For information needed in the preparation of this summary, the writers are most indebted to Mr. Earl Wallace, President of the Kentucky Oil and Gas Association, and Mr. D. J. Jones, Geologist, Kentucky Department of Mines and Minerals, both of Lexington, who employed Mr. George L. Ballentine, Consulting Engineer of Charleston, W. Va., for two months to compile the total oil production for the state. To Mr. W. H. Keffer, of Ashland Refining and Transportation Co., Ashland, Ky., Mr. P. C. Mathews, General Superintendent for Jim Ellis, Mr. N. W. Shiarella, Geologist, Mr. J. W. Polkinghorn, Kentucky Natural Gas Co., all of Owensboro, as well as to Mr. Ballentine, the writers are indebted for information and statistics.

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[56] The Corniferous in this field is impregnated with SO_2.

[57] Due to high porosity of sand this field will probably show a recovery of 65 per cent. The recovery of entire pool estimated 2,500,000 barrels.

[58] Slightly (15 per cent) deeper than Floyd and Knott, owing to more eastern position in Appalachian trough, and Black shale thickens from 150 to 200 ft. in eastern Pike County.

[59] Similar to Floyd and Knott County except that Weir sand in Miss. series comes in at depth of from 1000 to 1400 ft. Average thickness 50± ft. One to three pays separated by shale breaks.

[60] The Jett sand on one lease varies in thickness from 5 to 52 feet.

[61] In the Canada Maxon sand gas pool of Pike County structure is directly a controlling factor.

[62] Shallow sand production in central and eastern Martin County are more controlled by the Warfield anticline and fault than is similar production in Floyd and Knott counties.

[63] Structure, especially minor structures are of very little or no importance in Kentucky's gas development. Depositional conditions, such as alterations from sands to shales, old sand shore limes, and leaching of limes are of far greater importance. In most cases production shows no relation whatsoever to minor folds.

[64] The (Hardinsbury) Jones sand of the Lindsay Taylor pool, although 40 ft. thick, carries oil only in the top 12 ft., and the lower part of sand carries large amounts of water. In most of the offset dry holes the sand became too shaley to carry oil. Structure does not seem to be an important factor.

[65] Shallow test dry were made before 1920.

[66] Although 70 per cent of the gas development was after 1928, W. R. Jillson has fully outlined the development of 1926 in his Kentucky Geol. Survey Series VI, New Oil Pools of Kentucky.

Oil and Gas Development in Louisiana

By B. C. Craft,* Member A.I.M.E.

(New York Meeting, February, 1935)

Louisiana experienced deeper and increased drilling during 1934, resulting in the discovery of five new fields: Bosco, Acadia and St. Landry Parishes; Lake Hermitage, Plaquemines Parish; Roanoke, Jefferson Davis Parish; Gillis, Calcasieu Parish; and Four Isle, Terrebonne Parish. New sands were discovered at New Iberia, Iberia Parish; Lake Washington, Plaquemines Parish; Sligo, Bossier Parish; and in the Rodessa gas field, Caddo Parish. Other miscellaneous events worthy of mention are the continued leasing of prospective oil and gas lands in North and South Louisiana, extensive geophysical work in the Gulf Coastal area, and increased interest in the development of flank production on piercement type domes, resulting in the acquisition of flank acreage and the leasing of several shallow domes in the Gulf Coast and Interior salt-dome areas.

The total oil production for Louisiana during 1934 was 32,529,082 bbl., an increase of 6,929,280 bbl. over 1933. The total daily production at the end of the year from 2421 wells was 102,752 barrels.

North Louisiana

During the year, 144 oil wells and 68 gas wells were completed in North Louisiana as compared with 111 oil wells and 47 gas wells during 1933. The North Louisiana oil production was 9,274,050 bbl. as compared with 10,023,580 bbl. during 1933, a decline of 749,530 bbl. The normal decline in the old fields and especially in the Zwolle area was partly offset by increased production in the Converse field, Sabine Parish, and by acid treatment of wells in the Zwolle, Converse and Caddo fields. There were no new fields discovered during 1934.

During the year R. W. Norton enlarged the boundaries and reserves of the Rodessa gas field. A series of gas-bearing sands, was discovered in J. B. French, No. 1-B, sec. 34, 23 N. 16 W., below the oolitic lime found at 5500 ft. in which formation all previous wells had been completed. The total depth of this well was 5825 ft. Subsequent drilling has resulted in

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TABLE 1.—*Oil and Gas Production in Louisiana*

Line Number	Field, *Parish*	Age, Years to End of 1934	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934
	North Louisiana									
1	Caddo[1], *Caddo*	31	32,500	0	15,040	47,540	144,370,895	2,294,970	2,249,115	6,090
2	Red River—Bull Bayou, *DeSoto, Red River*	21	11,000	0	3,300	14,300	55,262,350	593,525	544,540	1,555
3	Lake Bisteneau, *Bienville*	19	0	0	600	600				
4	Elm Grove, *Caddo, Bossier*	19	320	0	14,600	14,920	2,902,550	125,295	135,120	365
5	Monroe, *Ouachita, Morehouse, Union*	19	0	0	123,340	123,340				
6	Bethany[2], Waskam, *Caddo*	19	0	0	1,800	1,800				
7	Homer, *Claiborne*	16	0	3,024	0	3,024	64,486,300	977,785	967,605	2,680
8	Haynesville, *Claiborne*	14	0	7,480	0	7,480	64,138,675	1,404,570	1,371,630	3,745
9	Shongaloo, *Webster*	14	70	0	5,680	5,750	89,030	10,370	7,485	25
10	Bellevue, *Bossier*	14	1,360	0	160	1,520	9,139,510	0	63,825	515
11	Sligo, *Bossier*	13	0	0	4,160	4,160				
12	Spring Hill—Sarepta, *Bossier, Webster*	13	570	0	1,120	1,690	1,136,675	191,900	162,970	354
13	Cotton Valley, *Webster*	13	3,900	0	2,700	6,600	14,515,425	199,500	190,765	500
14	Carterville, *Bossier*	11	720	0	2,720	3,440	1,338,755	85,905	92,810	241
15	Urania, *Grant, LaSalle, Winn*	10	3,700	0	0	3,700	19,152,935	933,480	1,124,145	3,325
16	Richland, *Richland*	9	0	0	49,280	49,280				
17	Pleasant Hill, *Sabine, DeSoto*	8	800	0	0	800	1,315,275	90,925	75,535	185
18	Zwolle, *Sabine*	7	64,000[3]	0	0	64,000	11,877,970	2,938,985	1,678,710	2,860
19	Epps, *East and West Carroll*	7	0	0	1,200	1,200				
20	White Sulphur Springs, *LaSalle*	7	80	0	0	80	12,290	0	0	0
21	Holly, *DeSoto*	5	80	0	0	80	748,265	74,850	65,385	155
22	Rodessa, *Caddo*	5	0	0	3,100	3,100				
23	Sugar Creek, *Claiborne*	4	0	0	2,800	2,800				
24	Clayton, *Concordia*	4	0	0	60	60				
25	Converse, *Sabine*	3	1,600	0	0	1,600	645,930	101,520	544,410	1,415
26	Total, North Louisiana		120,700	10,504	231,660	362,864	391,132,830	10,023,580	9,274,050	24,010
	South Louisiana									
27	Jennings, *Acadia*	34	235	0	0	235	50,829,208	406,250	451,991	1,448
28	Anse LaButte, *St. Martin*	33	25	0	0	25	784,112	13,850	11,850	32
29	Welsh, *Jefferson Davis*	32	50	0	0	50	580,835	16,180	9,831	35
30	Vinton, *Calcasieu*	25	265	0	0	265	40,507,001	1,380,860	1,141,041	2,855
31	Edgerly, *Calcasieu*	23	215	0	0	215	8,222,583	53,820	73,744	594
32	Pine Prarie, *Evangeline*	23	10	0	0	10	20,000	0	0	0
33	Houma, *Terrebonne*	23	0	0	720	720				
34	Bayou Bouillon, *St. Martin*	19	12	0	0	12	372,894	0	0	0
35	New Iberia, *Iberia*	18	25	0	0	25	136,067	0	63,720	300
36	Lockport, *Calcasieu*	11	270	0	0	270	12,537,744	951,765	712,388	1,931
37	Starks, *Calcasieu*	10	50	0	0	50	1,834,832	333,655	264,760	631
38	Sulphur, *Calcasieu*	9	50	0	0	50	7,163,795	887,095	1,280,036	3,612
39	Sweet Lake, *Cameron*	9	250	0	0	250	2,398,199	335,960	386,725	947
40	Fausse Pointe, *Iberia*	8	10	0	0	10	31,726	0	0	
41	Hackberry, *Cameron*	7	80	0	0	80	2,095,489	212,060	191,835	610
42	East Hackberry, *Cameron*	7	140	0	0	140	10,049,862	1,805,560	1,728,862	4,881
43	Sorrento, *Ascension*	7	20	0	0	20	533,227	15,145	10,200	39
44	White Castle, *Iberville*	6	30	0	0	30	1,234,664	195,010	199,781	444
45	Port Barre, *St. Landry*	6	75	0	0	75	4,004,032	1,005,790	980,211	3,590
46	Dog Lake, *Terrebonne*	6	10	0	0	10	7,313	0	0	
47	Bayou Blue, *Iberville*	6	30	0	0	30	61,837	0	0	
48	Black Bayou, *Cameron*	6	30	0	0	30	1,728,918	289,515	410,746	999
49	Lake Pelto, *Terrebonne*	6	20	0	0	20	158,922	18,460	1,271	0
50	Lake Barre, *Terrebonne*	6	100	0	0	100	9,133,532	3,072,685	1,797,082	5,133
51	Caillou Island, *Terrebonne*	5	30	0	0	30	1,711,502	342,715	1,362,782	5,318

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[a] Footnotes for column heads and explanation of symbols are on page 249.

[1] Includes the following districts: Cedar Grove, Shreveport, Jeems Bayou, Trees City, Monterey, Harts Ferry, Ferry Lake, Mooringsport, Gilliam, Pine Island, Vivian Dixie and Blanchard.

[2] Includes the part of each field in Louisiana and the Greenwood area.

[3] Scattered production over 64,000 acres.

the completion of two gas wells with an average daily production of 56,000,000 cubic feet.

In the Red River-Bull Bayou field, Bailey Gaunce et al., Jenkins, No. 1, sec. 35, 13 N. 12 W., was completed as a 6,000,000 cu. ft. gas well from 3577 ft. in the Glen Rose, opening up a new gas horizon for this field.

In the Sligo field, the Producers Oil and Gas Co., Inc., completed W. H. Werner No. 1, sec. 7, 17 N. 11 W., from a new sand at 3285 ft., for 16,500,000 cu. ft. of gas. The Woodley Petroleum Company's E. A. Schuler No. 5, sec. 13, 17 N. 12 W., was completed for 58,500,000 cu. ft. of gas from a new sand at 2792 feet.

An interesting repressuring project was started in the Homer field, Claiborne Parish. Results indicate it will prove highly successful.

Sabine Parish was the most active area during the year; however, there was a sharp decline in activity in the Zwolle and Converse fields. The decline in production was partly offset by the intensive use of acid.

Wildcatting has been extensively carried on in the east and southeast flanks of the Sabine uplift and on the flanks of the interior salt domes.

North Louisiana gas production increased 34,292,000,000 cu. ft. in 1934 over its 1933 figure. The Louisiana Department of Conservation gage of Nov. 1, 1934, shows an open-flow capacity of 4,951,019,000 cu. ft. per day from 885 wells in the Monroe field and 1,149,044,000 cu. ft. from 190 wells in the Richland field.

SOUTH LOUISIANA

Bosco.—The most important discovery during 1934 was the Bosco field in Acadia and St. Landry Parishes, 8 miles northwest of Lafayette. The

TABLE 1.—(*Continued*)

Line Number	Field, *Parish*	Age, Years to End of 1934	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934
52	Cameron Meadows, *Cameron*	4	20	0	0	20	556,399	51,250	479,864	1,589
53	Choctaw, *Iberville*	4	20	0	0	20	662,119	101,590	312,119	504
54	Lake Washington, *Plaquemines*	4	200	0	0	200	704,137	186,967	359,804	1,051
55	Leeville, *Lafourche*	4	210	0	0	210	5,057,161	361,285	4,268,595[3a]	13,972
56	Iowa, *Calcasieu, Jefferson Davis*	4	0	1,000	0	1,000	9,154,129	3,365,060	5,276,444	17,149
57	Darrow, *Ascension*	3	20	0	0	20	15,839	9,925	5,109	15
58	Gueydan, *Vermilion*	3	50	0	0	50	489,261	164,770	104,853	1,364
59	Bosco, *Acadia, St. Landry*	1	1,000	0	0	1,000	1,061,878	0	1,061,878	7,428
60	Lake Hermitage, *Plaquemines*	1	10	0	0	10	405	0	405	0
61	Roanoke, *Jefferson Davis*	1	120	0	0	120	238,736	0	238,736	1,451
62	Four Isle, *Terrebonne*	1	10	0	0	10	20,412	0	20,412	358
63	Gillis, *Calcasieu*	1	100	0	0	100	48,362	0	48,362	462
64	Total South Louisiana		3,792	1,000	720	5,512	174,147,132	15,576,222	23,255,032	78,742
65	Total, Louisiana		124,492	11,504	232,390	368,376	565,279,962	25,599,802	32,539,082	102,752

[3a] Estimated.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1934		At End of 1934				
	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	4,442	278	6	131,516	1,198	1,401	6	3,745	45	59	25	1,054	0	34	1,088
2	5,024	264	8	59,844	3,071	1,447	5	1,238	7	39	8	188	0	44	232
3				2,012	70	0	0	10	0	5	0	0	0	0	0
4	9,070	1,114	10	202,524	2,252	2,854	11	249	1	0	0	35	0	45	80
5				1,674,560	113,424	163,376	565	908	31	1	6	0	0	793	793
6				16,630	1,501	1,629	6	67	0	3	0	0	0	18	18
7	21,655	344	7	5,168	333	191	2	627	0	3	0	0	365	0	365
8	8,575	343	11	[4]	[4]	[4]	[4]	766	1	9	1	0	335	0	335
9	1,272	106	12	70,333	753	169	7	91	0	1	0	2	0	7	9
10	6,720	840	10	2,096	252	131	1	352	11	3	0	50	0	2	52
11				[5]	[5]	3,386	12	58	5	0	0	0	0	37	37
12	1,994	181	30	25,469[6]	161[6]	29[6]	1	43	0	3	0	12	0	5	17
13	3,722	338	7	69,524	2,150	2,167	7	278	0	0	0	75	0	33	108
14	1,859	116	4	16,955	33	0	0	133	1	0	0	57	0	0	57
15	5,176	575	16	5	0	0	0	443	1	1	5	206	0	0	206
16				400,389	56,449	32,373	108	284	1	10	13	0	0	195	195
17	1,644	103	4					57	0	1	0	42	0	0	42
18	185	23	21					307	36	57	0	140	0	0	140
19				750	49	142	1	5	1	0	1	0	0	4	4
20	154	17						12	0	0	2	0	0	0	0
21	9,353	850	26	0	0	0	0	12	0	0	0	6	0	0	6
22				23,329	7,784	13,934	48	16	6	0	0	0	0	16	16
23				15,693	3,695	4,238	18	9	1	0	0	0	0	11	11
24				11	0	0	0	1	0	0	1	0	0	0	0
25	404	40	20					105	64	16	3	74	0	0	74
26			192	2,716,808	193,175	227,467	7,971	9,816	212	211	65	1,941	700	1,244	3,885
27	216,295	3,933	41					515	4	0	3	36	0	0	36
28	31,365	896	8					34	0	0	0	4	0	0	4
29	11,617	1,542	3					66	0	0	0	11	0	0	11
30	152,857	1,698	32					438	8	7	1	80	0	0	80
31	38,245	294	35					175	3	0	3	15	0	0	15
32	2,000	67	0					4	0	0	0	0	0	0	0
33				14,295	0	0	0	10	0	0	0	0	0	0	0
34	31,075	1,110	0					10	0	0	0	0	0	0	0
35	9,071	197	300					5	1	0	0	1	0	0	1
36	46,436	464	62					80	5	2	1	29	0	0	29
37	36,697	917	35					26	2	0	2	18	0	0	18
38	117,655	981	74					70	19	1	5	45	0	0	45
39	9,593	240	190					8	0	0	0	5	0	0	5
40	3,173	453						4	0	0	0	0	0	0	0
41	26,194	748	32					53	6	5	1	21	0	0	21
42	40,199	619	100					102	7	1	6	49	0	0	49
43	26,661	1,777	13					6	0	0	0	3	0	0	3
44	41,155	1,372	148					3	0	0	3	3	0	0	3
45	53,387	1,525	156					36	12	0	3	24	0	0	24
46	713	59						1	0	0	1	0	0	0	0
47	2,061	103						6	0	0	0	0	0	0	0
48	5,736	48	166					13	5	1	2	7	0	0	7
49	7,946	145	0					2	0	0	1	0	0	0	0
50	91,335	1,218	321					31	6	1	4	16	0	0	16
51	5,705	63	760					8	5	0	0	7	0	0	7

[4] Included with Homer.
[5] Included with Elm Grove.
[6] Spring Hill gas production; Sarepta gas production included with Cotton Valley.

Superior Oil Producing Company's P. O. Hernandez No. 1, sec. 34, 8 S. 3 E., encountered the Discorbis ("Hernandez") sand from 7831-56 ft., the Heterostegina ("Mire") sand from 8028 to 8060 ft. and the Marginulina ("Richard") sand from 8614 to 8629 ft. This well was completed in the Discorbis sand through perforated casing from 7846 to 7850 ft. with an initial production of 2400 bbl. of 37° A.P.I. oil per day. During the last six months of the year 21 wells were completed and the proven limits extended until it now embraces over 1000 acres. Gas sands overlie the Discorbis and Marginulina oil sands. While no wells have been completed in the third, fourth, and fifth Marginulina sands, good saturation has been reported from cores taken in these zones.

The structure at Bosco consists of a broad, slightly arched dome cut by several faults and having at least 100 ft. of productive closure and possibly as much as 200 feet.

Roanoke.—In May, 1934, the Shell Petroleum Corporation completed its Kratzer No. 1, sec. 12, 9 S. 4 W., Roanoke prospect, Jefferson Davis Parish, for an initial production of 47 bbl. of 37° A.P.I. oil per hour from 8660 to 8682 ft. This sand is probably in the Marginulina zone. During the last six months four wells have been completed, resulting in three oil wells and one gas well. The producing limits of the field have not been defined. In the course of development Humble Oil and Refining Company's Kratzer No. 1, sec. 11, 9 S. 4 W., found a second producing sand in the Marginulina zone from 8814 to 8830 ft., which produced 4,000,000 cu. ft. of gas and approximately 40 bbl. of distillate. Later a third sand was encountered in Humble Oil and Refining Company's Devilbiss

TABLE 1.—(*Continued*)

	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells								
									During 1934		At End of 1934					
Line Number	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
52	27,817	695	265					8	4	0	0	6	0	0	6
53	33,106	828	168					7	3	0	4	3	0	0	3
54	3,521	135	88					16	1	0	3	12	0	0	12
55	24,081	201	264					71	60	1	13	52	0	0	52
56	9,154	173	365	185	0	185	*y*	51	34	0	2	0	48	0	48
57	792	23	7					2	0	0	0	2	0	0	2
58	9,785	316	34					5	0	0	0	4	0	0	4
59	1,062	12	530					21	21	0	0	21	0	0	21
60	41	3	0					1	1	0	1	0	0	0	0
61	2,387	48	725					4	4	0	0	4	0	0	4
62	2,041	73	358					1	1	0	0	1	0	0	1
63	484	32	462					2	2	0	0	2	0	0	2
64			198	14,480	0	185		1,895	214	19	59	481	48	0	529
65				2,731,288	193,175	227,652		11,711	426	230	124	2,422	748	1,244	4,418

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1934					Pressure, Lb. per Sq. In.			Character of Oil Approx. Average during 1934				
			Number of Wells						Average at End of		Gravity A. P. I. at 60° F.				
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Injection into Reservoir[d]	Initial	1933	1934	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	2,067[7]	[10]	0	1,054	0	0	G	415–1,650	900[37]	361[37]–250	25–46	14–26	38	0.5–0.35	A, P
2	823–2,648–3,577	787–2,600–	0	188	0	0	G	350–975	100	295	41.5	40	41	0.25	P
3	2,018–2,553	1,993–2,544	0	0	0	0		800–1,056	220	0	32	28	30	0.40	M
4	1,645[8]	1,621[8]	0	35	0	0		400–1,100	20–90–110	25–70–90					
5	2,205	2,145	0	0	0	0		1,050	501	466					
6	1,823	1,718[11]	0	0	0	0		400–1,325	500[38]	450[38]	38	35	36	0.80	P
7	1,345–2,065	1,280–2,040	0	365	0	0	G	*x*	0	0	35	32	33	0.40	P
8	2,805–4,844	2,790–4,559	0	335	0	0	G	*x*	12	12	30	28	29	0.35	M
9	2,680	2,665	0	2	0	0		1,050	40	40	20	19	19.2	0.80	A
10	370–1,035–1,815	360–1,010–1,790	0	50	0	0		175–750	*o, y*	250					
11	883[9]–1,745–2,480	845[9]–1,710–2,445	0	0	0	0		375–1,825	733	0[9]–250–320					
12	2,691–3,063–3,165	2,686–3,059–3,143	0	12	0	0		1,300	88	96	28	25	26	0.32	M
13	2,547–4,652	2,532–4,350	0	75	0	0		1,080–1,750	225	225	30–52	29–48	31	0.25–0.09	M, P
14	3,085–3,170	3,080–3,143	0	57	0	0		1,250	0	0	44	38	41	0.27	P
15	1,536	1,529	0	191	0	15		*x*	0	0	22	19	20.5	0.30	A
16	2,447	2,349[12]	0	0	0	0		1,125	214	155	42	38	40	0.30	P
17	3,237	3,175	0	42	0	0		1,350	0	0	455	38	40	0.10	P
18	2,440	2,280	0	137	0	3		750	0–250	0					
19	2,344	2,336	0	0	0	0		1,080	987	1,060					
20	804	794	0	0	0	0		0	0	0					
21	2,851	2,838	0	6	0	0		900	840	800	45	38	41	0.22	P
22	5,676	5,560	0	0	0	0		2,400	3,250	1,985					
23	4,420	4,314	0	0	0	0		1,800	1,500	1,020					
24	1,438	1,415	0	0	0	0		630	630	630	46	42	43	0.15	P
25	1,922–3,232	1,617–3,150	2	72	0	0		[36]	[36]	[36]					
26			2	2,621	0	18									
27	1,944	1,833[13]	2	34	0	0		295–550	0–150	0–140	26–34.5	21–34.5	28	0.17	A
28	1,506	1,351[14]	0	4	0	0		200	30	30	24	22	23	0.37	A
29	1,158	1,148	0	11	0	0		50	0	0	22.6	22	22.3	0.15	A
30	2,752	2,685[15]	1	79	0	0		*x*	105	55	32	20	29.4	0.30	A
31	3,145	3,107[16]	1	14	0	0		*x*	20	50	22	19	20	0.18	A

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[7] Average depth of all wells completed.

[8] Average bottoms of wells and tops of productive zones are as follows: 840–804 ft., 1556–1548 ft., 1915–1896 ft., and 2496–2469 ft.

[9] Two wells completed in the Glen Rose. Average to top and bottom of sand 4108–4263 ft ; pressure 1800 lbs. One well completed in the 2750-ft. sand.

[10] Producing horizons and average depth to top of horizons are as follows: Nacatoch, 1000 ft.; Chalk, 1437 ft.; Buckrange 1823 ft.; Tokio 2260 ft.; and Trinity 3647 ft.

[11] Also produces from contact of Upper and Lower Cretaceous, contact of Washita and Fredericksburg, Glen Rose and Lower Glen Rose. The producing horizons are found at the following average depths: Nacatoch sand, 1000 ft.; Buckrange, 1950; 2300-ft. horizon, 2250–2350; Adams sand, 2600–2700; Augurs 2900–3000; 3100, 3200 and 3300-ft. sands; 1st Lower Glen Rose horizon, 4645 ft.; 2nd Glen Rose horizon, 4697.

[12] One well completed in the Glen Rose at 2936 ft.

[13] Production obtained from following zones: 1515–2075 ft.; 3915–4330 ft.; 7300–7392 ft.; and 8600–8760 ft.

[14] Production obtained from following zones: 400–760 ft.; 1380–1535 ft.; and 1645–1890 ft.

[15] Production obtained from following zones: 1100–1170 ft.; 1510–2150 ft.; 2200–2800 ft.; 2915–3272 ft.; and 3395–3665 ft.

[16] Production obtained from following horizons: 1060–1558 ft.; 2314–2355 ft.; 2655–2795 ft.; 2890–2920 ft.; 3025–3095 ft;. 3100–3264 ft.; 3405–3680 ft.; and 3715–4055 ft.

[36] Wells flow for a few days after acid treatment.

[37] Pressures and saturation in Blanchard area.

[38] Pressure on Augurs sand. Pressure on Nacatoch 70 lb.; 2300 ft. sand, 230 lb.; 2600 ft. and 330 lb.

TABLE 1.—(*Continued*)

	Average Depth, Ft.		Oil Production Methods at End of 1934					Pressure, Lb. per Sq. In.			Character of Oil Approx. Average during 1934				
			Number of Wells						Average at End of[e]		Gravity A. P. I. at 60° F.				
Line Number	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Injection into Reservoir[d]	Initial	1933	1934	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
32	1,269	1,200	0	0	0	0		x	0	0					
33	2,469	2,448	0	0	0	0		1,040	0	0					
34	3,050	2,838[17]	0	0	0	0		1,600	0	0					
35	2,458	2,398[18]	1	0	0	0		400		400	24.9	24.9	24.9	0.26	A
36	4,558	4,533[19]	12	14	0	3		2,200	1,800	775	41	23	33	0.12	A
37	2,272	2,224[20]	2	16	0	0		700	430	197	32	18	25	0.30	A
38	4,160	4,136[21]	14	21	0	10		850	790	150	36	19	26	0.31	A
39	6,284	6,262[22]	4	1	0	0		1,050	55	147	32	29	28.5	0.12	A
40	1,170	1,137	0	0	0	0		x	0	0					
41	3,331	3,296[23]	2	19	0	0		500	0	92	32	19	20	0.37	A
42	3,700	3,668[24]	14	35	0	0	G	2,400	2,325	1,625	32	20	28	0.44	A
43	1,639–4,351	1,624–4,345	1	2	0	0		625–1,600	325–1,600	325–1,600	31	26	28	0.38	A
44	5,188–5,836	5,170–5,700	1	0	2	0		875	270	250	25	23	24	0.36	A
45	3,407	3,368[25]	5	19	0	0		640	350	350	27	20	25.5	0.33	A
46	1,068	1,056	0	0	0	0		0	0	0					
47	2,319	2,262[26]	0	0	0	0		300	0	0					
48	4,535	4,446[27]	6	1	0	0		600	350	205	23.8	18	21	0.11	A
49	1,373	1,274	0	0	0	0		200	0	0	16.8	16.8	16.8	0.55	A
50	3,836	3,777[28]	16	0	0	0		600	600	193	35.5	33	34	0.32	A
51	4,555	4,510[29]	7	0	0	0		600–980	600–1,000	616–1,032	34	32	33	0.26	A
52	4,113	4,080[30]	5	1	0	0		1,500	0	791	41	27	37	1.0	A
53	3,107	3,052[31]	1	2	0	0		600	600	400	29.5	25.5	28.7	0.15	A
54	1,154	1,135	12	0	0	0		450	147	160	19	18	18.5	0.73	A
55	3,729	3,660[32]	35	14	3	0		1,300	315	175	30	23	26	0.40	A
56	6,941	6,920[33]	47	0	1	0		2,510	2,500	1,400	49.7	25.4	41	0.37	M
57	4,035–4,827	4,008–4,820	0	2	0	0		240	0	0					
58	3,972	3,924[34]	2	2	0	0		1,150	120	50	27.5	27.1	27.3	0.12	A
59	7,918–8,085–8,684	7,901–8,060–8,662	21	0	0	0		900–3,100		2,150	45.6	36	38.5	0.17	M
60	4,269	4,257	0	0	0	0		590		0	24	24	24	0.06	A
61	8,477	8,454[35]	3	0	0	0		2,025		2,025	38.4	37	38	0.10	M
62	5,639	5,611	1	0	0	0		980		980	44.2	44.2	44.2	0.18	M
63	6,765	6,754	2	0	0	0		1,500		1,100	34.1	34.1	34.1	0.68	A
64			218	291	6	13									
65			220	2,912	6	31									

[17] Production obtained from following horizons: 410–450 ft.; 3025–3210 ft.; 3235–3360 ft.; and 4284–4341 ft.

[18] Producing zones: 1008–1070 ft., 1665–1710 ft., 2690–2855 ft., and 3805–3828 ft.

[19] Producing zones: 1000–1095 ft., 2960–3237 ft., 3385–3400 ft., 3620–3875 ft., 4315–4435 ft., 4705–4924 ft., 5100–5665 ft., 5970–5985 ft., and 6445–6623 ft.

[20] Producing zones: 860–1178 ft., 1205–1240 ft., 3411–3422 ft., and 3692–3721 ft.

[21] Producing zones: 2760–2950 ft., 3150–3575 ft., 3650–3835 ft., 3985–4200 ft., 4300–4525 ft., 4775–5175 ft., and 5325–5700 ft.

[22] Producing zones: 5170–5195 ft., 5632–5718 ft., 5900–5925 ft., 6795–6815 ft., and 7335–7387 ft.

[23] Producing zones: 3010–3400 ft., 3810–3975 ft., and 4275–4350 ft.

[24] Producing zones: 2610–3100 ft., 3900–4015 ft., 5990–6140 ft., and 7232–7242 ft. Nine producing sands have been reported.

[25] Producing zones: 3150–3200 ft., 3320–3420 ft.,and 3710–3717

[26] Production from sands between 3650–4080 ft.

[27] Producing zones: 965–980 ft., 4380–4520 ft., 5080–5220 ft., and 6615

[28] Producing zones: 1710–1735 ft., 1900–2300 ft., and 3575–3590 ft.

[29] Producing zones: 3206–3243 ft., 3965–4006 ft., and 5980–6030 ft.

[30] Producing zones: 3500–3580 ft., 3800–3960 ft., 4700–4750 ft., and 5260–5275 ft.

[31] Producing zones: 2030–2050 ft., 2410–2560 ft., 2880–2900 ft., and 4100–4400 ft.

[32] Oil and/or gas produced from sands found at the following average depths: 2800–3000 ft., 3300, 3560, 3670, 3760, 3837 4200 and 4400 ft.

[33] Production obtained from sands found at the following average depths: 4515, 5135, 5585, 6525, and 6935 ft. Most wells have been deepened to or completed in the zone of 6935 ft.

[34] Producing zones: 3450–3555 ft., 3980–4300 ft., and 4820–4850 ft.

[35] Producing zones: 7800–7918 ft., 8660–8682 ft., and 8814–8830 ft.

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1934		Producing Rock							Deepest Zone Tested to End of 1934	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1934[42]	Name	Depth of Hole, Ft.
1	926	0.22[37]		CreU, CreL	C, S	Por	16	A	876	L Trinity	6,351
2	y	0	Nacatoch[10], "Chalk Rock," Basal CretU, Glen Rose	CreU, CreL	S	Por	19	AF	304	Glen Rose	6,149
3			Ozan, Tokio	CreU	S	Por	35	D	11	Cret L	3,002
4	1,025	0.15[39]	Nacatoch, Ozan, Tokio	CreU	S	Por	8	A	42	Cret L	5,382
5	1,017	0.13	"Monroe Gas Rock"	CreU	LS	23	50	A	93	Glen Rose	4,155
6		0–0.24	Nacatoch[11], Buckrange	CreU, CreL	S, L	Por	120	A	50	Glen Rose	3,575
7	3,300	15.0[40]	Nacatoch, Buckrange[41]	CreU	S	Por	63	DF	194	Glen Rose	4,504
8	1,100	1.50[40]	Buckrange, Glen Rose	CreU, CreL	S	Por	25	A	61	Glen Rose	5,092
9	971	0	Buckrange	CreU	S	Por	12	A	26	Glen Rose	4,750
10	970	0.34	Nacatoch, Buckrange, Trinity	CreU, CreL	S	Por	8	DF	107	L Trinity	6,137
11	972–1,057	0–0.24	Nacatoch, Buckrange, Tokio, Fredericksburg, Glen Rose	CreU, CreL	S, L	Por	100	D	5	Glen Rose	4,276
12	994–1,046	0.07–0.33	Buckrange, Tokio	CreU	S	Por	11	A	19	Glen Rose	5,120
13	866–1,004	1.5	Buckrange, Glen Rose	CreU, CreL	S, A, S	27, 24	11	A	26	L Trinity	7,006
14	994–1,046	0.07–0.33	Buckrange, Tokio	CreU	S	Por	16	A	49	Trinity ?	3,476
15			Cane River-Wilcox contact	Eoc	S	Por	9	T	143	Tckio	6,463
16	1,060	0.34	Tokio, "Monroe Gas Rock," Glen Rose	CreU, CreL	S, LS	Por	76	A	39	L Trinity	2,836
17			Washita	CreL	S	Por	16	A	23	Glen Rose	5,063
18			Saratoga, Marlbrook, Anona, Ozan	CreU	C, S	Crev	8	AF	395	Glen Rose	7,155
19	998	0	"Monroe Gas Rock"	CreU	LS	Por	8	D	10	Glen Rose[45]	3,142
20			Jackson	Eoc	S	Por	9	N	8	Wilcox	2,435
21			Eagle Ford	CreU	S	Por	11	N	27	Fredericksburg	3,373
22	1,060	0.50–0.40	Glen Rose	CreL	LS	Por	25	NF	18	L Trinity	6,658
23	1,125	0.56	Glen Rose	CreL	L	Por	20	A	13	L Trinity	4,722
24	984	0	Basal Jackson	Eoc	S	Por	25	N	6	Wilcox	3,705
25			Nacatoch ?, Saratoga, Anona, Ozan, Washita	CreU, CreL	M, C, S	Por	10	D	52	Glen Rose	4,433
26									2,597		
27			"Fleming," Marginulina ?	Mio	S	Por	55	Ds	111	Vicksburg	8,903
28			"Citronelle," "Fleming," Jackson	Plio, Mio, Eoc	S	Por	35	Ds	79	Jackson	1,500[46]
29			Plio-Mio contact	Plio, Mio	S	Por	8	D	43	Vicksburg	6,017
30			PlioL, "Fleming," Marginulina	Plio, Mio	S	Por	90	Ds	196	Jackson	6,553
31			PlioL	Plio	S	Por	130	Ds	86	Jackson ?	8,414

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[39] Gasoline content of gas from deep horizon; gas from other sands is dry.
[40] Produce casinghead gas.
[41] Goes also under name of Oakes sand or Haynesville sand.
[42] Dry holes drilled in fields and those drilled in defining producing limits.
[45] Abandoned in igneous rock.
[46] Deepest well abandoned at 6204 ft. in Miocene.

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1934		Producing Rock							Deepest Zone Tested to End of 1934	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1934[42]	Name	Depth of Hole, Ft.
32			"Fleming"	Mio	S	Por	30	Ds	31	"Fleming"	5,112
33			Uppermarine Mio	Mio	S	Por	10	D	13	Miocene	5,645
34			"Fleming"	Mio	S	Por	28	Ds	43	Vicksburg	3,910[47]
35			PlioL, "Fleming"	Plio, Mio	S	Por	46	Ds	32	"Fleming"	4,300
36			"Fleming," Heterostegina zone	Mio	S	Por	100	D	17	Marginulina ?	7,902
37			PlioL, Cap rock, "Fleming"	Plio, X, Mio	S	Por	40	Ds	55	Jackson ?[48]	7,207
38			"Fleming," Heterostegina	Mio	S	Por	120	Ds	33	Heterostegina	9,250[49]
39			"Fleming"	Mio	S	Por	40	Ds	6	Mio ?	8,070
40			"Fleming"	Mio	S	Por	7	Ds	17	"Fleming"	5,119
41			"Fleming"	Mio	S	Por	35	Ds	102	Jackson ?[48]	3,424[50]
42			Cap rock, "Fleming"	X, Mio	S	Por	65	Ds	63	Jackson ?[48]	3,035[51]
43			Cap rock, Vicksburg	X, Olig	A, S	Por	15	Ds	24	Vicksburg	5,725[52]
44			"Fleming"	Mio	S	Por	30	Ds	5	"Fleming"	6,170
45			Marginulina?	Mio	S	Por	35	Ds	17	Heterostegina	4,610[49]
46			PlioL	Plio	S	Por	12	Ds	13	MioU	6,347
47			"Fleming"	Mio	S	Por	20	Ds	10	"Fleming"	6,103
48			Cap rock, MioU, Heterostegina	X, Mio	L, S	Por	120	Ds	18[43]	Heterostegina	6,200[53]
49			Upper Marine Mio	Mio	S	Por	55	Ds	8	MioU	5,659
50			Upper Marine Mio	Mio	S	Por	75	Ds	11	MioU	7,162
51			Upper Marine Mio	Mio	S	Por	90	Ds	6	MioU	5,981
52			"Fleming"	Mio	S	Por	40	Ds	5	MioU	7,100
53			"Fleming"	Mio	S	Por	40	Ds	13[44]	"Fleming"	6,290
54			Cap rock, Super Cap sand	X, Plio	L, S	Por	26	Ds	29	Mio	5,860[54]
55			Upper Marine Mio	Mio	S	Por	120	D	13	MioU	7,300[49]
56	1,102	050	"Fleming," Heterostegina, Marginulina	Mio	S	Por	53	D	8	Marginulina	7,590
57			Upper Marine Mio	Mio	S	Por	34	Ds	7	MioU	6,052
58			"Fleming"	Mio	S	Por	31	Ds	9	Discorbis	9,379[55]
59			Discorbis, Heterostegina, Marginulina	Mio	S	Por	90	D	5	Vicksburg	9,925[55]
60			Upper Marine Mio	Mio	S	Por	15	Ds	12	MioU	6,472
61			Heterostegina, Marginulina	Mio	S	Por	50	D	7	Marginulina	9,612[55]
62			Upper Marine Mio	Mio	S	Por	28	Ds	8	MioU	6,923
63			Marginulina	Mio	S	Por	15	D	2	Marginulina	7,916
64									1,157		
65									3,759		

[43] Includes 7 sulfur tests.
[44] Includes 8 sulfur tests.
[47] Deepest well abandoned at 6471 ft. in Lower Miocene
[48] Abandoned in heaving shale.
[49] Abandoned in salt.
[50] Deepest well abandoned at 7834 ft.
[51] Deepest well abandoned 8334 ft.
[52] Deepest well abandoned at 6565 ft.
[53] Deepest test abandoned at 6631 ft
[54] Abandoned in salt at 6179 ft.
[55] Drilling

TABLE 2.—*Summary of Drilling Operations in Louisiana*
(Figures in body of tabulation represent number of holes.)

Parish	Completed Prior to January 1, 1935												Completed during 1934												Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes											Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes											Productive Wells (For Details, See Table 1)		
	Total Depths, Ft.										Total		Total Depths, Ft.										Total			
	1,000–500	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000	8,000–9,000	9,000–10,000			500–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000	8,000–9,000	9,000–10,000			Within Fields	Exploratory
Acadia	0	23	30	22	10	9	1	3	7	0	105	526	0	1	0	1	0	0	0	2	3	0	7	15	9	2
Allen	0	0	0	0	0	0	1	0	1	0	2	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
Ascension	1	8	5	4	10	3	3	0	0	0	34	8	0	0	0	0	1	0	2	0	0	0	3	0	1	0
Assumption	10	4	1	0	0	0	1	0	1	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Avoyelles	1	3	4	2	0	0	0	0	0	0	10	0	0	0	1	0	0	0	0	0	0	0	1	0	0	2
Beauregard	0	2	0	6	2	0	1	0	3	1	15	0	0	0	0	0	0	0	1	0	3	1	5	0	0	1
Bienville	2	6	39	27	4	1	0	0	0	0	79	10	0	0	0	3	0	1	0	0	0	0	4	0	0	2
Bossier[1]	36	51	133	79	6	2	1	0	0	0	308	717	1	1	7	5	0	0	0	0	0	0	14	17	0	5
Caddo	77	226	690	63	18	1	2	0	0	0	1,077	[2]3,902	12	6	6	2	0	0	0	0	0	0	26	51	3	12
Calcasieu	2	26	82	70	48	21	20	7	3	1	[2]280	[3]1,538	0	0	3	5	3	3	4	5	3	0	26	53	23	5
Caldwell	4	13	8	8	1	0	0	0	0	0	34	0	0	1	0	1	0	0	0	0	0	0	2	[illegible]	0	0
Cameron	0	18	8	19	6	10	3	4	0	0	68	184	0	1	0	2	1	3	2	1	0	0	10	22	18	1
Catahoula	1	4	6	15	1	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Claiborne	7	137	216	59	9	3	1	0	0	0	432	1,402	0	0	0	0	1	0	0	0	0	0	1	[illegible]	0	1
Concordia	0	4	3	3	0	0	0	0	0	0	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
De Soto	5	37	226	86	5	1	2	0	0	0	362	343	0	7	8	4	0	0	0	0	0	0	19	5	1	8
East Baton Rouge	0	3	3	0	0	0	1	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
East Carroll	0	7	3	4	0	0	0	0	0	0	14	4	0	0	0	2	0	0	0	0	0	0	2	1	0	0
East Feliciana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Evangeline	0	7	13	1	5	1	0	0	0	0	27	4	0	0	1	0	0	0	0	0	0	0	1	0	0	1
Franklin	0	5	8	2	1	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grant	1	39	32	2	0	0	0	0	0	0	74	10	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Iberia	31	13	4	12	13	6	2	0	0	0	81	[4]189	0	0	0	3	1	0	0	0	0	0	4	91[6]	2	1
Iberville	5	3	4	7	4	4	3	0	0	0	30	16	0	0	0	0	1	1	0	0	0	0	2	3	3	0
Jackson	0	5	8	8	0	0	0	0	0	0	21	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Jefferson	0	0	1	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jefferson Davis	4	17	15	8	10	8	2	3	1	0	68	99	0	0	0	0	0	2	0	3	1	0	6	24	9	1
Lafayette	0	1	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lafourche	0	34	5	4	13	6	2	2	0	0	66	71	0	0	0	1	8	2	1	2	0	0	14	60	13	4
La Salle	15	125	22	7	0	1	1	0	0	0	171	432	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Lincoln	1	0	13	12	3	0	0	0	0	0	29	0	0	0	0	1	1	0	0	0	0	0	2	0	0	0
Livingston	0	0	4	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Madison	1	1	0	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morehouse	4	4	16	21	0	0	0	0	0	0	45	228	0	0	1	1	0	0	0	0	0	0	2	5	0	0
Natchitoches	6	40	37	18	3	2	0	0	0	0	106	0	1	0	1	2	0	2	0	0	0	0	6	0	0	5
Orleans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ouachita	2	0	37	12	1	0	0	0	0	0	52	525	0	0	2	0	0	0	0	0	0	0	2	21	0	0
Plaquemines	5	10	3	1	0	2	0	0	0	0	21	[5]94	1	4	0	1	0	0	0	0	0	0	6	54[7]	2	1
Point Coupee	2	3	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rapides	0	4	5	17	13	1	0	0	0	0	40	0	0	0	1	2	0	0	0	0	0	0	3	0	0	2
Red River	3	24	155	24	0	0	0	0	0	0	206	897	1	2	4	1	0	0	0	0	0	0	8	2	1	1
Richland	5	5	43	7	1	0	0	0	0	0	61	284	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Sabine	12	49	404	66	17	2	0	0	0	0	550	466	0	12	47	7	1	0	0	0	0	0	67	100	17	1
St. Bernard	1	1	1	0	0	0	2	0	0	0	5	0	0	1	1	0	0	0	1	0	0	0	3	0	0	1
St. Charles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
St. Helena	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
St. James	0	1	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
St. John the Baptist	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
St. Landry	1	0	4	8	5	0	0	0	2	1	21	46	0	0	0	2	2	0	0	0	2	1	7	22	1	2
St. Martin	16	54	27	17	14	10	6	1	0	1	146	44	0	0	0	0	0	0	0	1	0	1	2	0	0	0

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[1] Seventy-two wells abandoned between 100–500 ft.
[2] Incomplete.
[3] Includes 712 sulfur wells.
[4] Includes 180 sulfur wells.
[5] Includes 77 sulfur wells.
[6] Includes 90 sulfur wells.
[7] Includes 51 sulfur wells.

No. 1-B, sec. 11, 9 S. 4 W., from 7888 to 7918 ft. in the Heterostegina zone. This well was completed flowing 29 bbl. per hour of 38.4° A.P.I. oil on a ⅜-in. choke.

The structure is apparently a broad dome with numerous small faults. Early development indicates that the sands are very lenticular.

Gillis.—Another important discovery was opened in the Gillis or Castle Mills area in Calcasieu Parish, about six miles northeast of Lake Charles. Union Sulphur Company's Barbe Estate No. 2, sec. 11, 9 S. 8 W., found production from 12 ft. of Marginulina sand at 6760 to 6772 ft., and was completed flowing 180 bbl. of 31.4° A.P.I. oil per day on a ¼-in. choke. The area was recently extended ½ mile northeast by the completion of the same company's No. 1 State, which was completed for an initial production of 1500 bbl. per day, from 6759 ft. While the field has not been defined, it is considered that the area is an important reserve.

Four Isle.—The Four Isle dome in Terrebonne Parish was proven productive when the Texas Company's State No. 4, sec. 24, 21 S. 16 E. was completed, flowing 2230 bbl. of 44.5° A.P.I. oil per day on a ½-in. choke from sand found at 5611 to 5639 ft. It is expected that this horizon will result in sustained production.

Lake Hermitage.—The first commercial production for the Lake Hermitage dome, Plaquemines Parish, was developed by Gulf Refining

TABLE 2.—(*Continued*)

Parish	Completed Prior to January 1, 1935												Completed during 1934												Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes											Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes											Productive Wells (For Details, See Table 1)		
	Total Depths, Ft.										Total		Total Depths, Ft.										Total			
	500–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000	8,000–9,000	9,000–10,000			500–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000	8,000–9,000	9,000–10,000			Within Fields	Exploratory
St. Mary	3	15	8	9	5	3	2	1	0	0	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
St. Tammany	0	0	2	2	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tangipahoa	0	0	2	1	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Tensas	1	1	1	2	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Terrebonne	2	20	21	9	12	11	8	3	0	0	86	53	1	5	0	3	3	4	2	2	0	0	20	12	12	1
Union	0	3	57	25	1	0	0	0	0	0	86	155	0	0	1	1	0	0	0	0	0	0	2	5	1	0
Vermilion	1	0	2	1	4	2	2	0	2	0	14	5	0	0	0	0	1	1	0	0	1	0	3	0	2	1
Vernon	1	1	3	5	2	1	0	0	0	0	13	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Washington	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Webster	5	21	85	41	9	3	0	1	0	0	165	413	0	0	5	1	0	0	0	0	0	0	6	1	0	0
West Baton Rouge	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Carroll	0	0	6	4	0	0	0	0	0	0	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Feliciana	0	1	3	3	3	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winn	6	45	15	6	6	0	0	0	0	0	78	13	1	3	0	0	0	0	0	0	0	0	4	0	0	0
Total	280	1,124	2,525	830	266	114	68	26	20	3	5,257	12,680	19	44	90	51	25	19	13	16	14	3	294	568	119	66

Company's LaFourche Basin Levee District No. 1, sec. 11, 18 S. 25 E., which was completed for 30 bbl. or 24° A.P.I. oil from sand at 4257 to 4269 ft. Production on the prospect has been rather disappointing, as the discovery well stopped flowing shortly after being completed.

Other Developments

Two new sands were added to the producing list during 1934. At New Iberia, Iberia Parish, Y. D. Spell et al., Bernard No. 1, sec. 54, 12 S. 7 E., opened the first important oil production for the field when it made 720 bbl. of 29.5° A.P.I. oil per day from sand at 3805 to 3828 ft. On the flank of the Lake Washington dome, Plaquemines Parish, Humble Oil and Refining Co. opened a new productive sand by the completion of its Cockrell Moran No. 23, sec. 14, 20 S. 26 E., when it came in for 384 bbl. of 23.7° A.P.I. oil on a ½-in. choke from sand at 4324 to 4337 ft.

The total oil production for South Louisiana during 1934 was 23,255,032 bbl. as compared with 15,576,222 bbl. during 1933. Development in new fields should result in a further increase during 1935.

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Oil and Gas in Michigan during 1934

By Theron Wasson,* Member A.I.M.E.

(New York Meeting, February, 1935)

Discoveries in Michigan, which at the beginning of the year 1934 indicated possible new areas, did not develop into fields of market-breaking proportions. Hart, Oceana County, developed small production from the Traverse lime. Edmore, Montcalm County, proved a small area for oil from the Traverse. West Branch, Ogemaw County, previously reported as Ogemaw, had quite a drilling campaign but was somewhat disappointing because wells were small and erratic. During the year, 30 wells were completed at West Branch, and at the end of the year 15 others in and around this field were under way. At West Branch the Traverse lime, found at 1800 ft., has thin porous streaks near the top, which make small wells; the Dundee lime at 2800 ft. produces from a porous zone of varying thickness. Over the entire field the Dundee wells average 10 to 20 bbl. per day. Acid treatment has materially increased production from some Dundee wells in this field. About 3000 acres have been proved productive from the Traverse and Dundee.

At the close of the year the well in Beaverton township, Gladwin County, is probably the most discussed of any in Michigan and may be opening a new field of some proportions. It had an initial production of 70 bbl. daily from the Dundee lime at 3830, which has decreased to 25 bbl. per day. Deeper drilling into the lime may increase production. During 1935 the area around this test will probably be the most active in the state. Structural conditions in Gladwin County, as in other parts of Central Michigan, are obscured by a thick mantle of glacial drift and it will take considerable drilling to outline subsurface conditions accurately.

The most important new shallow gas area of the year is around Edmore in Mecosta and Montcalm counties. Eight wells have been drilled to the Michigan stray and the upper Marshall sand, having a combined initial production of 30 million cubic feet. These gas wells are scattered over so wide an area that an estimate of proven territory cannot be made until more drilling is done. At the present time no gas is being sold from Edmore.

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The Big Rapids gas field in Austin township, Mecosta County, had eight producing wells at the end of the year, with total combined open-flow volume of 121 million cubic feet. An 8-in. line was recently completed from this field to Muskegon.

Six new gas wells were completed in the Vernon field of Isabella County. Gas from this field is sold for domestic use in Mt. Pleasant, Clare and Rosebush.

The Broomfield gas field had considerable development during the year; 24 new wells, with a total combined open flow of 33 million cubic feet, were added to the field. The gas is sold for domestic use in Midland, Saginaw, Bay City and surrounding towns. Broomfield marketed more gas than any other field this year.

The total oil production for 1934 from all fields was 10,616,766 bbl. This was from 979 wells. The Porter area, including Yost, produced 7,458,330 bbl., or nearly three-quarters of the yearly total. The old fields of Midland and Isabella[1] counties of the Central Michigan area held the lead in oil production established in previous years. The Porter-Yost field, which is an extension southeastward from Mt. Pleasant, had the greatest amount of new drilling. One hundred and eighty-six wells were drilled in the Porter-Yost field during 1934, bringing the total for that area to 294 producing wells.

TABLE 1.—*Oil and Gas Production in Michigan during* 1934

			Area Proved, Acres				Total Oil Production, Bbl.				Average Oil Production, Bbl.	
Line Number	Field, *County*	Age, Years to End of 1934	Oil	Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934	Per Acre to End of 1934[b]	Per Well Daily during Nov., 1934
1	Saginaw, *Saginaw*	10	1,660	0	0	1,660	1,194,185	53,924	47,681	130	719	1.3
2	Muskegon, *Muskegon*	7	4,200	200	0	4,400	6,235,099	274,445	156,891	429	1,484	2.4
3	Mt. Pleasant, *Midland, Isabella*	7	9,120	0	0	9,120	16,858,787	3,126,323	1,512,614	3,520	1,849	11.3
4	Leaton, *Isabella*	5	940	0	0	940	1,225,568	306,618	244,636	718	1,304	27.5
5	Vernon, *Isabella*	5	1,320	0	880	2,200	2,032,716	535,722	904,872	2,229	1,540	40.5
6	Porter-Yost, *Midland*	3	8,480	0	0	8,480	11,059,677	3,583,617	7,458,330	18,449	1,304	63.6
7	Hart, *Oceana*	2	500	0	0	500	109,636	46,404	63,454	330	219	13.7
8	West Branch, *Ogemaw*	1½	3,000	0	0	3,000	143,284	18,982	124,310	333	48	18.5
9	Edmore, *Mecosta, Montcalm*	1	160	0	0	160	104,169	1,660	102,508	285	614	95.0
10	Gratiot, *Gratiot*	8	0	0	400	400	0	0	0	0	0	0
11	Clare, *Clare*	5	0	0	300	300	0	0	0	0	0	0
12	Broomfield, *Isabella*	5	0	0	6,320	6,320	x	x	x	8	x	x
13	Big Rapids, *Mecosta*	1½	0	0	3,500	3,500	0	0	0	0	0	0
14	Beaverton, *Gladwin*	0	x	x	x	x	1,470	0	1,470	30	x	30
15	Isolated Wells, *Cass*	0	x	x	x	x	0	0	0	0	0	0
16	Isolated Wells, *Lapeer*	0	x	x	x	x	0	0	0	0	0	0
17	Isolated Wells, *Mason*	0	x	x	x	x	0	0	0	0	0	0
18	Isolated Wells, *Mecosta*	0	x	x	x	x	0	0	0	0	0	0
19	Isolated Wells, *Montcalm*	0	x	x	x	x	0	0	0	0	0	0
20	Total		29,380	200	11,400	40,980	38,964,591	7,947,695	10,616,766			

[a] Footnotes to column headings and explanation of symbols are on page 249.

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[1] Map of Michigan fields. *Trans.* A.I.M.E. (1934) **107,** 257.

The Federal allowable for the state averaged 30,400 bbl. per day for the year 1934. The Porter field was kept under proration during the entire year. At first it was given a flat allowable of 100 bbl. per well plus a small percentage. Later it was cut to 75 bbl. per well, and finally the flat allowable was reduced to 50 bbl. The other fields were not prorated.

Operators have been forced to build earthen pits to dispose of considerable salt water. So far these have proved satisfactory, although many are of a temporary nature. Wells in the Porter-Yost area produced more salt water than those in Mt. Pleasant.

The old Mt. Pleasant field and East Greendale extension had 310 wells producing at the end of the year. During 1934 there was little new drilling. Some repressuring work in the East Greendale extension helped to boost the production in this field for the year. Most wells in this old field show little salt water, and therefore are easy to operate.

In the Leaton field of Isabella County, now five years old, nine new producing oil wells were completed during the year. Early in 1934 an extension to the northwest was made, and to date four new wells have been completed in that direction. As a result of these new discoveries production for 1934 from this field did not decline as rapidly as in other old fields. Wells of the Leaton field are among the best in Michigan in their response to acid treatment.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells						Average Depth, Ft.		Oil Production Methods at End of 1934		
						During 1934		At End of 1934					Number of Wells		
	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Injection into Reservoir[d]
1	0	0	0	0	282	2	41	101	0	101	1,850	1,820	0	101	0
2	5,725	468	432[1]	1.5	410	12	44	143	23	166	2,075	2,050	0	143	0
3	x	x	628[2]	4	388	20	34	310	0	310	3,575	3,510	0	310	G-1
4	x	x	x	x	37	9	0	28	0	28	3,700	3,675	0	28	0
5	597	195	263	1.5	73	24	0	55	14	69	G-1,405– 0-3,725	1,395– 3,700	0	55	0
6	x	x	ch 229	1	307	186	8	294	0	294	3,450	3,405	25	269	0
7	x	x	x	x	22	8	2	16	0	16	1,900	1,860	0	16	0
8	x	x	x	x	30	26	3	27	0	27	1,750– 2,770	1,700– 2,650	0	27	0
9	x	x	x	x	12	11	1	3	8	11	3,120	3,045	0	3	0
10	3	0	1	x	8	0	4	0	4	4	510	500	0	0	0
11	0	0	0	0	7	0	0	0	7	7	1,420	1,400	0	0	0
12	2,163	446	1,235	4	44	24	5	1	38	39	1,350	1,300	0	1	0
13	x	x	199	3	8	4	0	0	8	8	1,450	1,425	0	0	0
14	0	0	0	0	1	1	0	1	0	1	3,830	3,885	1	0	0
15	0	0	0	0	1	1	0	0	0	0	x	x	0	0	0
16	0	0	0	0	1	1	0	0	0	0	x	x	0	0	0
17	0	0	0	0	4	4	0	0	0	0	x	x	0	0	0
18	0	0	0	0	2	2	0	0	0	0	x	x	0	0	0
19	0	0	0	0	2	2	0	0	0	0	x	x	0	0	0
20	8,488	1,109	2,987		1,639	337	142	979	102	1,081			26	953	G-1

The Vernon field continued to make a great deal of salt water, some wells producing as much as 2000 bbl. per day.

Several kinds of pumping equipment designed to handle large amounts of salt water and oil have been installed this year in the Porter field. The Carr pneumatic pumping head is one of the most successful and economical. So far no central powers have been installed at Porter.

In November, 1934, The Michigan Public Utilities Commission of Lansing published "Rules and Regulations Governing the Production, Transmission and Distribution of Natural Gas," under its order number 2883. Mr. E. L. Rawlins, of the U.S. Bureau of Mines, working in cooperation with the Public Utilities Commission and the Department of Conservation, has prepared a study of the gas reserves in the stray sand of Michigan, which should soon be published.

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TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1934			Producing Rock					Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
		Average at End of		Gravity A.P.I. at 60°F.										
	Initial	1933	1934	Weighted Average	Sulfur, Per Cent	Base[f]	Name	Age[g]	Character[h]	Porosity[i]	Structure[j]		Name	Depth of Hole Ft.
1	x	x	x	43	0.7	P	Berea	Miss	S	Por	A	y	Sylvania	3,970
2	x	x	x	37	1.4	P	Traverse, Monroe	Dev	LD	Por	A	y	St. Peter	4,754
3	x	x	x	42	0.2	P	Dundee	Dev	L	Por	A	22	Sylvania	4,821
4	x	x	x	43	0.4	P	Dundee	Dev	L	Por	A	14	Monroe	4,390
5	x	x	x	44	0.5	P	Stray Gas, Monroe Oil	Miss, Dev	S, LD	Por	AF	26	Monroe	3,700
6	x	x	x	42	0.3	P	Dundee	Dev	L	Por	A	16	Monroe	3,677
7	x	x	x	34	y	P	Traverse	Dev	L	Por	A	13	Dundee	2,407
8	x	x	x	36	0.3	P	Traverse, Dundee	Dev	L	Por	A	8	Sylvania	5,404
9	900	900	600	42	y	P	Stray, Marshall, Traverse	Miss, Dev	S, L	Por	Mc, ML	7	Monroe	3,700
10	x	x	x	0	0		Parma	Penn	S	Por	A	1	Dundee	3,100
11	590	x	x	0	y		Stray	Miss	S	Por	A	1	Monroe	4,055
12	550	x	x	46	y	P	Stray, Dundee	Miss, Dev	S, L	Por	A	7	Monroe	3,753
13	580	x	x	0	y		Stray, Marshall	Miss	S	Por	A	3	Dundee	3,790
14	0	0	0	42	y	P	Dundee	Dev	L	Por	?	0	Dundee	3,885
15	x	x	x	x	x	x	x	x	x	x	x		x	x
16	x	x	x	x	x	x	x	x	x	x	x		x	x
17	x	x	x	x	x	x	x	x	x	x	x		x	x
18	x	x	x	x	x	x	x	x	x	x	x		x	x
19	x	x	x	x	x	x	x	x	x	x	x		x	x
20														

[1] Character of gas: 1032 B.t.u. per cu. ft.; 1 gal. gasoline per M. cu. ft.

[2] Character of gas: 0.75 gal. gasoline per M. cu. ft.

TABLE 2.—*Summary of Drilling Operations in Michigan*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to January 1, 1935									Completed during 1934							Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes								Productive Wells	Dry and/or Near-dry Holes						Productive Wells		
	Total Depths, Ft.									Total Depths, Ft.								
	0–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	Total	(For Details, See Table 1)	0–1000	1000–2000	2000–3000	3000–4000	4000–5000	Total	(For Details, See Table 1)	Within Fields	Exploratory
Clare	0	6	0	3	8	0	0	17	7	0	1	0	0	1	2	0	0	0
Gratiot	4	2	7	14	0	0	0	27	8	0	0	1	4	0	5	0	0	0
Isabella	11	8	1	84	4	0	0	108	315	11	0	0	26	1	38	60	11	2
Mecosta	0	9	0	3	1	0	0	13	15	0	7	0	0	0	7	11	0	5
Midland	0	1	0	64	1	0	0	66	534	0	1	0	15	0	16	203	12	4
Montcalm	0	0	0	14	1	0	0	15	9	0	0	0	11	0	11	8	0	2
Muskegon	0	34	87	1	1	0	0	123	410	0	1	5	0	0	6	12	0	0
Oceana	0	18	19	3	1	0	0	41	22	0	6	5	0	0	11	8	1	1
Ogemaw	0	7	6	3	0	1	0	17	30	0	4	3	2	0	9	26	4	8
Saginaw	1	34	20	15	1	0	1	72	282	1	4	0	5	0	10	2	0	2
Alcona	2	2	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Allegan	0	11	5	0	0	0	0	16	0	0	1	0	0	0	1	0	0	1
Alpena	6	4	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0
Antrim	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arenac	0	1	3	2	0	0	0	6	0	0	0	2	2	0	4	0	0	0
Barry	0	2	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1
Bay	0	5	1	5	0	0	0	11	0	0	2	0	1	0	3	0	0	0
Benzie	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Berrien	9	4	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0
Branch	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Calhoun	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Cass	2	4	6	0	0	0	0	12	1	1	0	0	0	0	1	1	0	0
Charlevoix	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Cheboygan	0	2	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Clinton	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0
Crawford	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Delta	0	1	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	1
Eaton	0	1	6	0	1	0	0	8	0	0	0	0	0	0	0	0	0	0
Emmet	3	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Genessee	0	1	5	0	0	0	0	6	0	0	0	2	0	0	2	0	0	0
Gladwin	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1	0	1
Hillsdale	0	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	2
Huron	0	4	0	3	1	0	0	8	0	0	0	0	1	0	1	0	0	0
Ingham	0	1	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Ionia	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0
Iosco	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Jackson	0	2	3	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Kalamazoo	0	1	1	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Kalkaska	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Kent	0	0	3	3	1	0	0	7	0	0	0	0	0	0	0	0	0	1
Lake	0	0	2	2	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Lapeer	1	3	5	0	0	0	0	9	1	1	2	3	0	0	6	1	0	6
Leelanau	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Lenawee	3	3	4	1	0	0	0	11	0	0	0	0	0	0	0	0	0	1
Livingston	4	11	1	1	0	0	0	17	0	0	0	0	0	0	0	0	0	2[1]
Macomb	8	4	3	1	0	0	0	16	0	0	0	0	0	0	0	0	0	1[1]
Manistee	1	6	6	0	0	1	0	14	0	0	0	0	0	0	0	0	0	1[1]
Mason	1	1	11	4	0	0	0	17	4	0	0	0	0	0	0	4	0	1
Missaukee	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Monroe	3	9	12	1	0	0	0	25	0	0	0	1	0	0	1	0	0	0
Montmorency	2	1	0	0	0	0	0	3	0	0	1	0	0	0	1	0	0	0
Newaygo	0	1	11	6	0	1	0	19	0	0	0	0	1	0	1	0	0	1
Oakland	0	4	2	0	0	0	0	6	0	0	1	0	0	0	1	0	0	0
Osceola	0	0	0	4	0	0	0	4	0	0	0	0	3	0	3	0	0	0
Osteco	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ottawa	0	4	3	2	1	0	1	11	0	0	0	0	0	0	0	0	0	0
Presque Isle	0	2	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Roscommon	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1
St. Clair	4	6	6	0	1	0	0	17	0	3	0	0	0	0	3	0	0	0
St. Joseph	1	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1
Sanilac	0	4	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Shiawassee	0	3	12	0	0	0	0	15	0	0	0	2	0	0	2	0	0	3
Tuscola	0	0	2	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Van Buren	1	8	3	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0
Wayne	3		3	0	1	0	0	7	0	1	0	0	0	0	1	0	0	1
Washtenaw	1	2	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Wexford	0	0	0	3	1	0	0	4	0	0	0	0	0	0	0	0	0	0
Total	73	244	272	249	26	3	2	869	1639	18	32	25	71	2	148	337	28	50

[1] One old well being drilled deeper.

Oil and Gas Development in Mississippi

By B. C. Craft*, Member A.I.M.E.

(New York Meeting, February, 1935)

Development and exploratory work in Mississippi during 1934 was rather active, resulting in the expansion of the proven area and the drilling of a number of important wildcat wells.

Mississippi showed a decrease in drilling operations during 1934. There were 36 completions from 18 counties during this period compared with 58 completions from 22 counties during 1933. There was a considerable decrease in activity in the Jackson gas field in Hinds and Rankin counties with only 9 completions, resulting in 8 gas wells and 1 dry hole compared with 17 gas wells, 2 oil wells and 7 dry holes during 1933.

Leasing and geophysical work was reported from several sections of Mississippi last year. Extensive exploration and drilling were carried on in Lamar, Hancock, Pearl River, Greene and Stone counties and on the flanks of the Jackson anticline. Exploration will be continued in these areas during 1935.

Four important wildcats were completed during 1934, all of which were reported as being structurally high, but without having important shows of oil or gas. These tests were: Hix and Germany's, J. J. Newman Lumber Co. No. 1, sec. 21-4N.-15W., Lamar County, abandoned at 3520 ft. in the Wilcox; United Gas Public Service Company's Davis No. 1, sec. 30-1N.-5W., Greene County, abandoned at 7439 ft.; Gulf Refining Company's May L. Williams No. 1, sec. 33-5S.-17W., Pearl River County, abandoned at 4800 ft.; and Clarke County Oil Company's S. B. Kirkland No. 1, sec. 10-2 N.-16E., abandoned at 4002 ft. in the Eutaw. Another interesting wildcat was Gulf Refining Company's Dantzler Lumber Co. No. 6, sec. 22-4S.-11W., Stone County, abandoned at 7700 ft. (according to reports below the Selma chalk).

A total of 114 of the 132 gas wells completed in the Jackson gas field are still producing and have a combined open-flow capacity of 4,145,696,000 cu. ft. Four of the abandoned gas producers were never connected to the lines.

The open-flow capacity of three wells in the Amory field is approximately 1,000,000 cu. ft. Producing against a line pressure of 50 lb., the demand during December greatly exceeded the capacity.

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TABLE 1.—*Oil and Gas Production in Mississippi*

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres			Total Oil Production, Bbl.				Average Oil Production, Bbl.		
			Oil	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934
1	Amory, *Monroe*	9	0	640	640							
2	Jackson, *Hinds, Rankin*	5	40	7,500	7,540	11,200	7,500	1,700	[1]	280	28	[2]
	Total		40	8,140	8,180	11,200	7,500	1,700				

Line Number	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							Average Depth, Ft.		Oil Production Methods at End of 1933		Pressure, Lb. per Sq. In.[e]		
						During 1934		At End of 1934						Number of Wells			Average at End of	
	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Pumping	Gas-lift	Initial	1933	1934
1	1,556	182	164	8	4	0	0	0		3	3	2,402	2,393			680	325	180
2	34,838	9,195	9,006	36	132	8	2	6		108	110	2,433	2,426	1	1	1,050	967	960
	36,394	9,377	9,170		136	8	2	[illegible]	2	111	113			1	1			

Line Number	Character of Oil, Approx. Average during 1934					Character of Gas, Approx. Average during 1934		Producing Rock					Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1934	
	Gravity A.P.I. at 60° F.															
	Maximum	Minimum	Weighted Average	Sulfur Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.			Name	Depth of Hole, Ft.
1						1,000	0	Hartselle	Mis	S	10	8	MU	2	Fort Payne	3,045
2	13.6	13.6	13.6	1.8	A	931	0	Selma	CreU	C	30	10	A	36	Trinity	4,027[3]
														41		

[b] Footnotes to column headings and explanation of symbols are on page 249.

[1] Wells are shut in the greater part of the time.

[2] Probably produce 50 bbl. of oil and 1000 bbl. of salt water.

[3] Abandoned in igneous rock.

TABLE 2.—*Summary of Drilling Operations in Mississippi*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1935											Completed during 1934									Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes										Productive Wells	Dry and/or Near-dry Holes								Productive Wells		
	Total Depths, Ft.											Total Depths, Ft.										
	500–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000	8000–9000	Total	(For Details See Table 1)	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000	Total	(For Details See Table 1)	Within Fields	Exploratory
Adams	0	0	1	0	1	0	0	0	0	2		0	0	0	0	0	0	0	0			0
Alcorn	0	0	1	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Amite	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			1
Attala	0	1	0	1	0	0	0	0	0	2		0	0	0	0	0	0	0	0			0
Benton	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Bolivar	0	0	0	1	0	0	0	0	0	1		0	0	0	0	0	0	0	0			1
Calhoun	0	1	0	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Carroll	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Chickasaw	0	2	1	0	0	0	0	0	0	3		0	0	0	0	0	0	0	0			0
Choctaw	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Claiborne	0	3	0	0	0	0	0	0	0	3		0	0	0	0	0	0	0	0			0
Clarke	0	2	1	0	3	0	0	0	0	6		0	1	0	1	0	0	0	2			1
Clay	0	0	1	0	1	0	0	0	0	2		0	0	0	0	0	0	0	0			0
Coahoma	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Copiah	0	2	2	0	0	0	0	0	0	4		0	0	0	0	0	0	0	0			0
Covington	1	1	0	3	2	0	1	0	1	9		0	0	0	0	0	0	0	0			0
DeSoto	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Forest	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Franklin	0	0	0	1	1	0	0	0	0	2		0	0	0	1	0	0	0	1			0
George	0	0	2	1	0	0	0	0	0	3		0	0	0	0	0	0	0	0			0
Greene	0	0	0	0	0	1	0	1	0	2		0	0	0	0	1	0	1	2			0
Grenada	0	0	1	0	1	0	0	0	0	2		0	0	0	0	0	0	0	0			0
Hancock	0	0	0	0	1	0	0	0	0	1		0	0	0	1	0	0	0	1			0
Harrison	0	0	1	1	0	0	0	0	0	2		0	0	0	0	0	0	0	0			1
Hinds	0	4	22	10	2	2	0	0	0	40	65	0	0	0	0	0	0	0	0	5	1	0
Holmes	0	0	1	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Humphreys	0	0	0	1	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Issaquena	0	0	0	2	0	0	0	0	0	2		0	0	1	0	0	0	0	1			1
Itawamba	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Jackson	1	1	4	3	1	1	0	0	0	11		0	0	0	0	0	0	0	0			0
Jasper	0	0	1	1	0	1	0	0	0	3		0	0	0	0	0	0	0	0			0
Jefferson	0	1	2	0	0	0	0	0	0	3		0	0	0	0	0	0	0	0			0
Jefferson Davis	0	0	0	1	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Jones	0	0	0	0	2	0	0	0	0	2		0	0	0	1	0	0	0	0			0
Kemper	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Lafayette	1	0	0	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Lamar	0	2	0	3	0	0	0	0	0	5		2	0	2	0	0	0	0	4			0
Lauderdale	0	0	2	4	0	0	0	0	0	6		0	0	0	0	0	0	0	0			1
Lawrence	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Leake	0	0	0	1	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Lee	1	0	0	1	0	0	0	0	0	2		0	0	0	0	0	0	0	0			0
Leflore	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Lincoln	0	0	1	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Lowndes	1	0	2	0	0	0	0	0	0	3		0	0	0	0	0	0	0	0			0
Madison	1	0	3	2	1	0	0	0	0	7		0	1	0	0	0	0	0	1			0
Marion	0	0	1	0	0	0	0	0	0	1		0	1	0	0	0	0	0	1			0
Marshall	0	0	2	1	0	0	0	0	0	3		0	0	0	0	0	0	0	0			0
Monroe	3	0	3	5	1	0	0	0	0	12	4	0	0	0	0	0	0	0	0	0	0	2
Montgomery	0	0	0	0	1	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Neshoba	0	1	0	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Newton	1	0	1	1	0	0	0	0	0	3		0	0	1	0	0	0	0	1			0
Noxubee	0	1	0	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Oktibbeha	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Panola	0	0	1	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Pearl River	0	0	1	2	1	0	0	0	0	4		0	0	1	1	0	0	0	2			0

TABLE 2.—(*Continued*)

County	Completed Prior to Jan. 1, 1935											Completed during 1934									Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes										Productive Wells	Dry and/or Near-dry Holes								Productive Wells		
	Total Depths, Ft.											Total Depths, Ft.										
	500–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000	8000–9000	Total	(For Details See Table 1)	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000	Total	(For Details, See Table 1)	Within Fields	Exploratory
Perry	0	0	0	1	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Pike	0	0	1	0	1	0	0	0	0	2		0	0	0	1	0	0	0	1			0
Pontotoc	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Prentiss	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Quitman	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Rankin	1	0	13	7	4	3	1	0	0	29	67	0	1	0	1	3	1	0	6	3	0	0
Scott	1	0	0	0	0	1	0	0	0	2		0	0	0	0	0	0	0	0			0
Sharkey	0	0	0	2	0	0	0	0	0	2		0	0	0	0	0	0	0	0			0
Simpson	0	0	2	0	0	0	0	0	0	2		0	1	0	0	0	0	0	1			1
Smith	0	0	0	1	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Stone	0	0	2	1	0	0	0	1	0	4		0	0	0	0	0	0	0	0			0
Sunflower	0	0	0	4	0	0	0	0	0	4		0	0	0	0	0	0	0	0			0
Tallahatchie	0	0	3	2	0	0	0	0	0	5		0	0	0	0	0	0	0	0			0
Tate	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Tippah	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Tishomingo	0	1	1	0	0	0	0	0	0	2		0	0	0	0	0	0	0	0			0
Tunica	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			0
Union	0	1	0	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Walthall	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			1
Warren	1	1	5	3	1	1	0	0	0	12		0	0	1	0	0	0	0	1			0
Washington	0	0	2	1	0	0	0	0	0	3		0	0	0	0	0	0	0	0			1
Wayne	0	0	0	0	0	1	0	0	0	1		0	0	0	0	1	0	0	1			0
Webster	0	2	0	0	0	0	0	0	0	2		0	0	0	0	0	0	0	0			0
Wilkinson	0	0	0	1	0	0	0	0	0	1		0	0	1	0	0	0	0	1			0
Winston	0	0	1	1	0	0	0	0	0	2		0	0	0	0	0	0	0	0			1
Yalobusha	0	0	1	2	0	0	0	0	0	3		0	0	0	0	0	0	0	0			0
Yazoo	0	0	1	0	0	1	0	0	0	2		0	0	0	0	0	0	0	0			0
Total	13	27	90	72	25	12	2	2	1	244	136	2	5	7	7	5	1	2	29	8	1	12

Oil and Gas in Missouri*

By Frank C. Greene†

(New York Meeting, February, 1935)

The oil and gas industry in Missouri in 1934 continued along the same lines that have marked the previous years. One new gas pool has been opened, others have been extended and in one oil pool a 25-bbl. well was completed.

Missouri has no laws or regulations relating to drilling or the filing of well logs and the Geological Survey depends on its own scouting activities to obtain information. The data herein have been taken largely from a paper by the author recently published in the 58th Biennial Report of the State Geologist of Missouri. That report is available on application to H. A. Buehler, State Geologist, Rolla, Missouri, accompanied by ten cents in stamps, the amount of the postage.

The preliminary figures, subject to revision, indicate that before the end of December, 1932, there were 2495 completions, of which 320 were oil wells, 1139 were gas wells and 1036 were dry. Over half of the oil wells were drilled in the Richards-Stotesbury area of Vernon County and were pumped for only a short period of time. During the period 1933–34 there were 201 completions, of which 10 were oil wells with an initial daily capacity of 100 bbl., 90 were gas wells, with an open flow of 26,578,256 cu. ft., and 101 were dry.

The most active areas in drilling for gas in 1934 were the Marota area, sec. 17, T.49N., R.32W., Jackson County, the Grandview area in T.47N., R.33W., Jackson County, and the Plattsburg area in Clinton County. The Knoche oil pool in sec. 16, T.46N., R.33W., Cass County, was the scene of the only important oil development.

In the Marota pool nine wells were completed to the Squirrel sand, with a combined open flow of about 5,000,000 cu. ft. The pool is on a small symmetrical dome with a closure of at least 30 ft. The average depth of the wells is 450 ft. The Squirrel sand (Upper Cherokee, Pennsylvanian) had a thickness of 94 ft. in a near-by dry hole, but only the upper 30 or 40 ft. is drilled in the producing wells. The largest well was Woodson No. 1, with 1,100,000 cu. ft. The Missouri Valley Gas and Oil Co. and D. S. Hulse are the operators.

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† Geologist, Missouri Geological Survey and Water Resources, Rolla, Mo.

The West Grandview pool, opened in 1933 by Bartle and Marshall, in sections 3, 4, 9 and 10, T.47N., R.33W., Jackson County, was extended south by the Ruf Drilling Co. into sections 10 and 15. There are now 12 producing wells, mostly in the Peru sand (Henrietta) though a small amount of gas has been obtained in the Wayside (Pleasanton) and Squirrel sands. The combined initial output was nearly 6,000,000 cu. ft., but owing to the thinness of the Peru sand, averaging less than 10 ft., the decline has been rapid. The average depth of the wells is around 400 ft. The pool is on a small elongate structure trending north and south.

The Hammond pool, in sections 18, T.55N., R.31W., and 13, T.55N., R.32W., near Plattsburg, Clinton County, was developed further and 14 producers have been completed. The combined initial capacity was 6,200,000 cu. ft. in the Peru sand and Lexington coal horizon. Porter No. 2 came in for 2,332,000 cu. ft. in the Peru sand. The average depth is 500 ft. The pool is on a well defined dome with at least 40 ft. of east dip. R. M. Hammond discovered the pool and has drilled all the wells.

TABLE 1.—*Location and Area of Some Missouri Gas Pools*

Name of Pool	Location	County	Number of Feet of Closure	Elevation, Lowest Closing Contour	Acres within Closing Contour	Maps Published in Biennial Report[1]
Marota gas pool	sec 17, T. 49N., R. 32W.	Jackson	20	590	355	58th
Hammond gas pool	secs. 18 and 13, T. 55N., Rs. 31, 32W. Plattsburg, Mo.	Clinton	25	515	480	58th
Knorp gas pool	T. 46 and 47N., R. 30W.	Cass and Jackson	15	760	404	57th
Gas pools near Freeman, Mo.	sec. 11, T. 44N., R. 33W.	Cass	22	630	157½	57th
	secs. 12 and 13, T., 44N., R. 33W.	Cass	30	640	213½	57th
Gas pools between Freeman and Peculiar	secs. 5 and 6, T. 44N., R. 32W.	Cass	10	680	109	57th
	sec. 31 T. 45N., R. 32W.	Cass	19	720	36¼	57th
Avondale gas pool	secs. 6 and 7, T. 50N., R. 32W.	Clay	8	510	87	57th
	sec. 7, T. 50N., R. 32W.	Clay	24	510	177	57th
Long gas pool	SW.¼, sec. 27, SE.¼, sec. 28, NE.¼, sec. 33, NW.¼, sec. 34, T. 41N., R. 33W.	Bates	23	720	256	57th
Liberty gas pool	secs. 35 and 36, Tps. 51 and 52N., R. 32W.	Clay	32	500	680	57th
Lathrop gas pool	T. 55N., R. 30W.	Clinton	24	770	983	57th
Shawhan gas pool	T. 47N., Rs. 29 and 30W.	Jackson	16	720	171.2	57th
Independence gas pool	secs. 26 and 35, T. 50N., R. 32W.	Jackson	48	810	404	57th
Paradise gas pool	T. 53N., R. 32W.	Clay	24	490	1,728	57th

[1] References are to Biennial Reports of the State Geologist of Missouri.

Several other new gas areas have been found in Jackson and Clinton counties, but have not been fully developed.

The most important oil development in Missouri was an extension of the Knoche pool in sec. 16, T.46N., R.33W., Cass County. Seven wells have been drilled by Louis Knoche on the Clark lease. The wells are about 600 ft. deep and the production is from the Squirrel sand of the Cherokee formation. The sand is about 100 ft. thick, but the upper half or more is broken and shaly, and most of the oil is obtained in the lower 30 ft. The largest well made 8 bbl. before the shot and 25 bbl. per day on the pump after being shot. This pool is on an anticline with a sharp east dip and is elongated north and south.

The production in the pools mentioned is obtained from rocks of Pennsylvanian age.

TABLE 2.—*Oil and Gas Wells and Dry Holes of Record Drilled in Missouri*

County	Drilled to End of 1932			Drilled in 1933–34			Initial Product of Oil, Bbl.	Open Flow of Gas Wells, Cu. Ft.
	Oil	Gas	Dry	Oil	Gas	Dry		
Andrew	0	0	2					
Atchison	0	0	3					
Audrain	0	0	1					
Barry	0	0	2					
Barton	0	0	2					
Bates	0	37	49		1	6		431,000
Buchanan	0	0	6					
Butler	0	0	3					
Caldwell	0	1	9					
Cape Girardeau	0	0	1					
Carroll	0	0	2					
Carter	0	0	2					
Cass	8	194	166	8	7	15	95	1,357,440
Cedar	0	0	1					
Chariton	0	0	4					
Clay	1	94	85	0	8	13		1,337,000
Clinton	0	18	27	0	19	8		8,051,200
Crawford	0	0	1					
Dade	0	0	1					
Daviess	0	0	4					
DeKalb	0	0	2					
Dent	0	0	1					
Dunklin	0	0	1					
Franklin	0	0	2					
Gentry	0	0	1					
Grundy	0	0	3					
Harrison	0	0	10					
Henry	0	0	1			1		
Holt	0	0	2					
Howard	0	0	3					
Howell	0	0	2					
Jackson	130	781	463	2	55	58	5	15,401,616
Jefferson	0	0	1					
Johnson	0	1	14					
Knox	0	0	3					
Lafayette	0	2	3					
Lewis	0	0	2					
Linn	0	0	3					
Livingston	0	0	2					
Macon	0	0	1					
Madison	0	0	1					
Marison	0	0	1					
McDonald	0	0	2					
Mercer	0	0	2					
Miller	0	0	1					
Montgomery	0	0	1					
New Madrid	0	0	1					
Nodaway	0	0	5					
Perry	0	0	1					
Pettis	0	0	2					
Phelps	0	0	1					

TABLE 2.—(*Continued*)

County	Drilled to End of 1932			Drilled in 1933–34			Initial Product of Oil, BBl.	Open Flow of Gas Wells, Cu. Ft.
	Oil	Gas	Dry	Oil	Gas	Dry		
Pike	0	0	1					
Platte	0	9	37					
Polk	0	0	1					
Putnam	0	0	4					
Ralls	0	0	3					
Randolph	0	0	2					
Ray	0	2	16					
Ripley	0	0	1					
St. Charles	0	0	7					
St. Clair	0	0	3					
St. Louis	1	3	15					
Saline	0	0	1					
Scotland	0	0	2					
Scott	0	0	1					
Shelby	0	0	1					
Stoddard	0	0	10					
Sullivan	0	0	1					
Taney	0	0	1					
Vernon	180[a]	31	17					
Worth	0	0	4					
Total to End of 1932	320	1,139	1,036	10	90	101	100	26,578,256

[a] Oil wells listed under Vernon county are those on Pond's map—shows no dry holes; all are abandoned at present.

Oil and Gas Development in New Mexico in 1934

By C. E. Shoenfelt,* Member A.I.M.E.

The deepening of the General Crude Oil Company's No. 1 Meyers, NE. NE. SE. of sec. 22, 24S., 36E., in the Cooper area of Lea County, in April, 1934, resulted in the discovery of an oil field of major importance. The discovery well is an old well drilled by Cranfill & Reynolds and completed in July, 1929, in limestone at 3438 ft. for an initial production of 90,000,000 cu. ft. (estimated) of gas. Deepening operations were started early in April, 1934, and cores were taken from the old total depth of 3438 to 3508 ft. A Haliburton test taken through the drill stem at 3439 to 3460 ft. showed 50,000,000 cu. ft. of gas with an increase of 5,000,000 cu. ft. between 3461 and 3474 ft. When completed the well tested 12,000,000 cu. ft. of gas and 5000 bbl. of oil at 3474–3508 feet.

The new oil field—the result of this discovery—is between the Eunice and the Jal fields, closer to the productive area of Jal than to that of Eunice but far enough away from both to be considered a separate area. Eventually, all of these pools may be joined together by productive oil wells to form a single unit of large size. They lie in a general northwest-southeast alignment and the intervening areas have not been condemned by dry holes.

In the drilling campaign that followed this discovery, 24 wells were drilled, of which 23 were oil wells with combined initial productions of

Table 1.—*Oil and Gas Production in New Mexico*

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres	Total Oil Production, Bbl.			
			Oil	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934
1	Artesia, *Eddy*	10	3,000	4,107,373	200,552	217,852	612
2	Caprock, *Eddy*	8	1,500	1,861,007	399,318	679,951	1,948
3	Cooper, *Lea*	4	3,600	328,429[1]	29,434	261,560	2,212
4	Eunice, *Lea*	6	1,000	2,138,167	289,489	949,736	3,825
5	Getty, *Lea*	6	320	148,182	0	0	0
6	Hobbs, *Lea*	6	6,280	53,516,705	11,413,218	12,423,024	31,630
7	Hogback, *San Juan*	11	700	1,526,830	77,017	74,483	197
8	Hospah, *McKinley*	7	160	5,980	0	0	0
9	Jal, *Lea*	6	1,000	2,870,910	547,930	1,049,204	3,405
10	Lea, *Lea*	4	640	4,914,806	801,288	636,862	1,440
11	Rattlesnake, *San Juan*	11	600	3,000,367	262,026	266,115	753
12	Table Mesa, *San Juan*	9	320	375,177	29,130	32,689	90
13	Total		19,120	74,786,933	14,049,402	16,591,476	

[1] Prior to 1932 included with Jal.

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* Geologist, Petroleum Information, Inc., Denver, Colorado.

70,562 bbl., and one was a gas well with an initial open-flow capacity of 7,500,000 cu. ft. The new field—operating under proration—had a gross production of 261,560 bbl. of oil in 1934. At the close of 1934, there were four wells drilling, three wells were shut down, three rigs were up, and six locations had been released.

North Lea Pool.—The possible opening of a new pool in Lea County was indicated by the completion by The Texas Company of its No. 1 J. S. Lea, SW. SW. NW. of sec. 14, 20S., 34E. The new well is 3 miles north of the nearest producer. It was completed in August, 1934, after plugging back from 3688 ft. to limestone pay at 3555 to 3580 ft., and had an initial production of 118 bbl. of oil and 25 bbl. of water. The oil tested 32° A.P.I., or about 5° higher than the average crude for the Lea pool.

Operations have been suspended pending the completion and the approval, by the Secretary of the Interior, of a pooling agreement. In the meantime, a few additional wells have been started to determine the size and extent of the possible producing area.

Hobbs High Pool.—Eighteen wells were drilled to completion in the Hobbs High pool during the year, most of which were on the edges of the developed area on the northwestern and southeastern sides of the field and resulted in some extensions of the proved area.

The development around sec. 24, 18S. 37E., extended the productive area of the field a mile west and indicated that there is additional possibly productive acreage to the north and west. A single completion in sec. 34, 18S., 38E., extended the productive area about a mile to the east. All of the wells completed at Hobbs in 1934 were large and ranged in capacity from 3000 bbl. initially to over 12,000 barrels.

TABLE 1—(*Continued*)

Line Number	Average Oil Production, Bbl.			Number of Oil and/or Gas Wells							Average Depth, Ft.	
					During 1934		At End of 1934					
	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov. 1934	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone
1	1,369		3	344	13	6		194	30	224	2,343	
2	1,241		88	41	1	0		22		22	3,000	
3	91		80	35	25	0		28	1	29	3,757	
4	2,138		116	41	22	0		33	1	34	4,087	
5	463		0	13	0	0	3	0	0	0	1,367	
6	8,554		144	219	18	0		211	0	211	4,240	
7	2,191	146	32	15	0	0		6	0	6	742	727
8	35	35	0	12	0	0	4	0	0	0	1,804	1,794
9	2,871		94	51	18	0		36	1	37	3,320	
10	7,686		103	16	3	0		14	0	14	3,700	
11	5,000	82	31	38	6	2		24	0	24	796	735
12	1,172	146	15	13	0	0		6	0	6	1,335	1,328
13				838	106	8	7	574	33	607		

[b] Footnotes to table heads and explanation of symbols are on page 249.

The potential of the Hobbs pool on Jan. 1, 1934, was 1,278,894 bbl., which compares with potential production on Dec. 31, 1934, of 2,168,278 bbl., an increase of 890,384 bbl. and is based on larger potentials assigned as a result of acidization which more than offset decreases due to lower potentials assigned as a result of bottom-hole pressure tests.

At the beginning of the year 1934 there were 183 units of 40 acres each. This compares with 202 productive units of 40 acres each at the close of the year. Water units increased from 18 at the beginning of the year to 35 at the end of the year. The daily average allowable on Jan. 1, 1934, was 33,178 bbl. and at the end of the year 33,476 barrels.

Jal Pool.—The productive area of the Jal pool was greatly extended during 1934 with the completion of 19 wells, all of which were productive either of oil or gas. New oil production from 18 wells totaled 18,500 bbl., estimated on the basis of short gages and in a great many instances after acid treatment.

Eunice Pool.—The productive area of the Eunice pool was extended on all sides by the completion of 22 wells in 1934, but the limits of the field in any direction were not defined. New production from 20 oil wells, based on short gages and in a number of instances after acid treatment, amounted to 26,800 bbl., or an average of 1340 bbl. per well. The developed area at the end of the year was approximately four miles long by one mile wide, the general trend being from northeast to southwest, except that to the southeast of the field, about 5 miles, The Ohio Oil Co. completed a gas well at a total depth of 4350 ft. that since has been plugged back and completed for 100 bbl. of oil daily.

TABLE 1.—(*Continued*)

Line Number	Oil Production Methods at End of 1934: Number of Wells: Flowing	Oil Production Methods at End of 1934: Number of Wells: Pumping	Character of Oil, Approx. Average during 1933: Gravity A.P.I. at 60° F.: Weighted Average	Character of Oil: Sulfur, Per Cent	Character of Oil: Base[f]	Producing Rock: Name	Producing Rock: Age[g]	Producing Rock: Character[h]	Producing Rock: Porosity[i]	Producing Rock: Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Deepest Zone Tested to End of 1933: Depth of Hole, Ft.
1	0	194	37	0.87	M	Dolomite zone	Per	D	Fis		D	120		
2	0	22	36	1.00	M	Dolomite zone	Per	D	Fis		D	19		
3	24	4	35	*y*	M	Carlsbad	Per	L	Fis		?	6		
4	0	33	27	1.65	M	Carlsbad	Per	L	Fis		D	7		
5	0	0	21	1.20	A	Carlsbad	Per	L	Fis		D	10		
6	211	*y*	27.5	1.05	M	Carlsbad	Per	L	Fis		D	8	San Andres	
7	0	6	56	0.00	P	Dakota	CreU	S	*y*	15	D	9		
8	0	0	27	0.15	M	Mesa Verde	CreU	S	*x*	10	D	8	Dakota (CreU)	3,283
9	29	8	37.5	1.97	A	Carlsbad	Per	L	Fis		?	14		
10	6	8	27.5	1.53	M	Carlsbad	Per	L	Fis			2		
11	0	24	64.8	0.04	P	Dakota	CreU	S	*y*	61	D	14	Goodrich (Pen)	7,370
12	0	6	58.0	0.04	P	Dakota	CreU	S	*y*	7	D	7		
13	270	305										224		

TABLE 2.—*Summary of Drilling Operations in New Mexico*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1935										Completed during 1934							Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes									Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes						Productive Wells (For Details, See Table 1)	Within Fields	Exploratory
	Total Depths, Ft.								Total		Total Depths, Ft.					Total			
	0–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000			0–1000	1000–2000	2000–3000	3000–4000	4000–5000				
Bernalillo	0	0	0	0	0	1	0	0	1	0									
Catron	0	1	0	0	0	0	0	0	1	0									
Chaves	14	18	14	7	3	2	0	0	58	0		2				2			2
Colfax	1	2	3	1	2	0	0	0	9	0									
Curry	4	2	0	0	1	0	0	0	7	0									1
De Baca	8	2	0	2	3	0	0	0	15	0									
Dona Ana	3	1	0	1	0	0	0	0	5	0									
Eddy	36	45	335	69	8	1	0	0	494	246	5	12	10	5	2	34	14	3	7
Gaudalupe	3	2	4	1	2	0	0	0	12	0			1		1	2			2
Harding	2	0	1	0	0	0	0	0	3	0									
Hidalgo	2	2	0	0	0	0	0	0	4	0									
Lea	8	3	4	368	51	13	0	0	447	325			1	66	19	86	86	57	
Lincoln	0	0	1	0	0	0	0	0	1	0									
Luna	0	0	3	2	0	0	0	1	6	0									
McKinley	36	27	4	4	0	0	0	0	71	4	1					1			3
Mora	0	2	1	0	0	0	0	0	3	0									
Otero	1	2	1	1	0	0	0	0	5	0									
Quay	1	1	0	6	1	1	0	0	10	0									
Rio Arriba	4	9	4	1	0	0	0	0	18	0									1
Roosevelt	1	0	0	0	2	0	0	0	3	0									2
Sandovai	2	1	3	0	0	0	0	0	6	0									
San Juan	88	41	8	6	0	0	0	0	143	30	15	4				19	6	9	2
San Mguel	11	6	3	1	0	0	0	0	21	0	1					1			4
Santa Fe	1	1	2	2	0	0	0	0	6	0									2
Sierra	0	0	1	0	0	0	0	0	1	0									
Socorro	3	4	1	2	1	0	0	0	11	0									
Torrance	7	12	1	4	0	1	0	0	24	0	1	2				3			
Union	4	0	4	0	0	0	0	0	8	0									1
Valencia	0	3	2	3	4	1	1	0	14	0	1					1			4
Total	240	187	400	481	78	20	1	1	1407	605	24	20	12	71	22	149	106	69	31

Oil Production in Ohio, 1934

By Dewitt T. Ring,* Member A.I.M.E.

(New York Meeting, February, 1935)

Oil development in 1934 has been largely restricted to drilling offset and lease requirement wells. Practically no effort has been made to discover new fields, chiefly because of price structure and proration allowance. A summary of developments during 1934 of necessity is brief. No state agency is maintained for the collection of data. The State Bureau of Mines issues permits for drilling and inspects the plugging of wells in coal-bearing measures only. Therefore data are not in existence with which to compile tables similar to those in other papers of this symposium.

Forty-seven counties in the state produce oil, productive depths ranging from 100 to 5300 ft. Approximately 35 different formations in Ohio have produced either oil or gas. These reservoir rocks occur through a stratigraphic interval ranging in age from the shallow Goose Run sand of the Upper Pennsylvanian in Washington County to the St. Peter sand of Lower Ordovician in Seneca County. However, 75 per cent of these formations are unimportant from the standpoint of real production.

Most of the oil and gas in Ohio has been produced from the Clinton, Oriskany, Berea and Big Injun sands and the Trenton Lime. Of these, the Clinton is first and Berea second in importance.

Fields

The oil and gas-producing territory of the state can be grouped into five fields or districts, made up of a series of "pools" usually separated by nonproductive areas, and is in no sense a belt of continuous production.

Trenton Field of northwestern Ohio, is scattered through 15 counties. Development began in 1885. This field reached its peak in 1896 with a production of 20,575,138 bbl. for the year. For 1934, production had declined to 990,000 bbl. The oil is classified as Lima grade.

Clinton Field extends from the Ohio River in Lawrence County to Lake Erie in Lorain, Cuyahoga and Ashtabula counties. First Clinton-

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sand gas production was in 1887; oil in 1899. The field produces Pennsylvania, Corning, Lodi and Cleveland grades of oil.

Oriskany Sand Field is in Guernsey, Muskingum, Coshocton and Tuscarawas counties. First development began in 1921. Production is Pennsylvania grade.

Eastern and Southeastern Field.—In this field both oil and gas are produced from the Berea and a number of shallower sands above this horizon, among which would be included the Squaw, Big Injun, Keener, Maxton, Salt Sand, Macksburg 700 Foot, Macksburg Stray, Macksburg 500 Foot, Second Cow Run, First Cow Run, Peeker, Mitchell and Goose Run. This field overlaps with the Clinton and Oriskany areas. Production is chiefly Pennsylvania grade.

Devonian Shale Gas Field, of southern Ohio, at present is limited to Lawrence and Scioto counties. Recoveries to date have been disappointing.

COMPLETIONS

During 1934 there were 1055 wells drilled in the state: 324 oil, 417 gas, 314 dry.

Of this total number, 30.7 per cent were classified as oil wells with a combined potential of 5586 bbl., or 15.3 bbl. per well; 39.5 per cent were gas wells with combined initial open flow of 333,378,890 cu. ft., or 799,469 cu. ft. per well; 29.8 per cent were dry holes.

PRODUCTION

Production during 1934 in the entire state, 4,270,000 bbl. (estimated), was distributed as follows[1]:

	TOTAL, BBL.	DAILY AVERAGE, BBL.
Pennsylvania grade	1,605,000	4,397
Corning grade	1,675,000	4,589
Lima grade	990,000	2,712

Average for the state was 11,100 bbl. daily (estimated). Geologically, the production might be apportioned as follows: Pennsylvanian, 15 per cent; Mississippian, 25; Devonian, 15; Silurian, 45.

Production for the year was kept within the proration allowable of 12,500 bbl. per day; Pennsylvania grade 4500 bbl., Corning 5000 bbl., Lima 3000 barrels.

While it is known that oil was produced in Ohio prior to 1876, there are no available production figures for these years. A conservative estimate of production from 1861 to 1876 should be placed at 3,000,000 barrels[1].

Production figures from 1876 through 1934 are given in Table 1.

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[1] Figures furnished by A. E. Faine.

TABLE 1.—*Production of Oil in Ohio*
(Thousands of Barrels)

Year	Production	Year	Production	Year	Production
1876	32	1895	19,545[a]	1915	7,825
1877	30	1896	23,941	1916	7,744
1878	38	1897	21,561	1917	7,751
1879	29	1898	18,739	1918	7,368
1880	39	1899	21,142	1919	7,736
1881	34	1900	22,363	1920	7,400
1882	40	1901	21,648	1921	7,335
1883	47	1902	21,014	1922	6,781
1884	90	1903	20,480	1923	7,085
1885	662	1904	18,877	1924	6,811
1886	1,782	1905	16,347	1925	7,212
1887	5,023	1906	14,788	1926	7,272
1888	10,011	1907	12,207	1927	7,593
1889	12,472	1908	10,859	1928	7,015
1890	16,125	1909	10,663	1929	6,743
1891	17,740	1910	9,916	1930	6,519
1892	16,363	1911	8,817	1931	5,327
1893	16,249	1912	8,969	1932	4,644
1894	16,792	1913	8,781	1933	4,264
		1914	8,536	1934	4,270[b]

[a] From 1895 to 1902 both inclusive, or for a period of 8 years, Ohio produced more oil than any other state.

[b] Estimate for 1934 is based on increased production of Corning grade oil.

REFINERIES AND GASOLINE PLANTS

There were 18 refineries in Ohio in 1934 with a capacity of 120,400 bbl. daily; four are shut down. Capacity of plants shut down, 9750 bbl. The Gulf Refining Co. put into operation a 13,000-bbl. refinery at Cincinnati during the year. Ohio produces only a small part of its refinery requirements, the remainder being supplied largely by Oklahoma, Texas and Michigan.

There were 20 natural gasoline plants in Ohio in 1933 with a capacity of 175,071 gal. daily; four shut down, having a capacity of 18,000 gallons.

NEW DEVELOPMENT

The most important shallow sand development in Ohio during recent years has been the Pultney Ridge field, in which 54 gas wells have been drilled, 48 of which were completed during 1934. The proven area of 1770 acres is confined to southeastern Wills and a small part of western Oxford townships, Guernsey County.

Production is from the first Berea sand, with an average thickness of 11 ft. Accumulation is controlled by a low anticlinal nose, which has a northeast-southwest trend and probably is a continuation of the Chaseville anticline in southern Guernsey and northern Noble counties. The structure of the Berea conforms to that of the surface beds.

The wells average 1420 ft. in depth; gas occurring between 415 and 455 ft. below sea level. Initial open-flow capacities range from 26,000 to 5,000,000 cu. ft.; average per well, 1,350,000 cu. ft. The initial rock pressure of the field was 585 lb. Woodburn No. 1 in sec. 21, Wills Township, had an initial open flow of 5,250,000 cu. ft.; this is the second largest gas well in the Berea sand drilled in the state.

In five wells in the southern edge of the present field, oil was encountered below 455 ft. subsea. These wells were rated from 2 to 16 bbl., averaging 7 bbl. after shooting.

The gas-producing area is practically defined at present, but the oil field may extend some distance down the dip to the south.

REPRESSURING AND RECONDITIONING WELLS

The first successful repressuring of the Clinton sand in Ohio was accomplished in 1934. The Chartiers Oil Co. began repressuring with natural gas, a lease located in Coal Township, Perry County, during December, 1933. The combined weekly production (8 wells) at the beginning of the experiment was 20 bbl. At the end of a 12-month period, it had been increased to an average of 250 bbl. per week. Depths of wells range from 3200 to 3400 feet.

Other similar experiments are contemplated for 1935. Prior to this time, the only efforts made toward rejuvenation of production in the Clinton sand was by reshooting and cleaning out. (Practically every method used to stimulate production has been used or experimented with in Ohio.) Repressuring with air began in the Marietta district almost 40 years ago. Vacuum, washing down, electrical heating, steaming and chemicals have also been tried. Acidization in the lime producing formations has been fairly successful; results are shown in Table 2.

TABLE 2.—*Results of Acidization in Lime Producing Formations*

Date	Formation	Number of Wells	Total
1932	Trenton	34	
	Niagaran	1	35
1933	Trenton	15	
	Niagaran	1	16
1934	Trenton	15	
	Oriskany	1	
	Niagaran	16	32

The ratio of increase in the Trenton territory has been approximately 1:4, according to figures furnished by the Dowell, Incorporated.

PRICE STRUCTURE

The price of crude oil in Ohio for the various grades is still far below the cost of production[2]. Prices for 1934 are listed in Table 3.

TABLE 3.—*Prices of Crude Oil in* 1934

Date, 1934	Grade	Price per Bbl.	Date, 1934	Grade	Price per Bbl.
Jan. 1 to 29	Pennsylvania	$1.92	Jan. 1 to Dec. 31	Corning	$1.32
Jan. 29 to May 1	Pennsylvania	1.97	Jan. 1 to Dec. 31	Lodi	1.32
May 1 to Nov. 6	Pennsylvania	2.06	Jan. 1 to Dec. 31	Cleveland	1.37
Nov. 6 to Dec. 6	Pennsylvania	1.82	Jan. 1 to Dec. 31	Lima	1.30
Dec. 6 to 31	Pennsylvania	1.57			

GAS PRODUCTION

According to the U.S. Bureau of Mines, estimated gas production for 1934 was 51,284,000 M. cu. ft.; for 1933 it was 47,929,000 cu. ft.

During 1933, consumption within the state was 92,762,000 M. cu. ft., of which 51.7 per cent was produced within the state, leaving 48.3 per cent to be imported.

Average initial open flow per well, based on yearly completions was as follows:

Year	Wells	Initial Open Flow, M. Cu. Ft.	Year	Wells	Initial Open Flow, M. Cu. Ft.
1934	417	799	1931	515	890
1933	327	864	1930	771	759
1932	312	909	1929	931	500

ACKNOWLEDGMENTS

The writer expresses his appreciation to Mr. J. S. Gillespie, Assistant Geologist, The Ohio Fuel Gas Co., for assembling and preparing much of the information in this paper; also to Messrs. J. R. Lockett, Assistant Geologist and L. W. Frost, Engineer, The Ohio Fuel Gas Co., Mr. A. E. Faine, Statistician, Ohio-Pennsylvania Grade Oil Producers Assn., and Mr. P. E. Fitzgerald of Dowell, Incorporated, for their contributions.

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[2] For verification of this statement see Cole Committee's Report, Volume 1, entitled Petroleum Investigation Hearing Before a Sub-Committee of the Committee on Interstate and Foreign Commerce, House of Representatives, 73rd Congress on House Resolution 441.

Petroleum Development in Oklahoma in 1934

By Lyndon L. Foley* and C. V. Millikan,† Members A.I.M.E.

The discovery of Bromide production in the Fitts field, shallow production in Jackson County of Southwestern Oklahoma, abundant production in the Edmond field, and discovery of many small pools in all parts of the state, were the events that made petroleum history in Oklahoma in 1934. Wildcatting was much more active, as evidenced by a number of new discoveries. There was no important development in the older fields. The rapid decline of the potential of the Oklahoma City field was an important feature of the history of the year.

The accompanying tabulation of oil fields (Table 1) is not complete. Many of the early records of operators and pipe line companies are lost and it will be impossible to work up complete statistics for a number of the older fields. The table includes most of the important fields of the state and includes fields of a number of different types. It is hoped that a great many additional fields may be worked up for next year's report.

Fitts Pool.—The Fitts pool, in Pontotoc County, was discovered in 1933. Before the middle of 1934, the Pennsylvanian sands yielded some oil at depths ranging from 1400 to 2800 ft. The Hunton series (Siluro-Devonian) produced most of the oil with considerable gas. In July, 1934, a well in sec. 25, T.2N., R.6E. was completed in the Bromide (Ordovician "Wilcox") with an initial production of about 300 bbl. a day. Less than a month later a second Bromide sand well was completed in sec. 30, T.2N., R.7E., which made over 200 bbl. an hour. This started an active drilling campaign, which was accelerated when some of the major companies paid good prices for adjacent acreage. At the end of the year, 23 wells had been completed and the rate of development was increasing rapidly. It is a major oil field. The Fitts pool opened a new geological province for oil production. The structure is a faulted anticline in a graben. The producing formation (Bromide) and the Arbuckle lime below it crop out about 2 miles south of present production. The Hunton lime crops out about 2½ miles north. The field is in a sharply folded and faulted area on the northeast side of the Arbuckle uplift. Heretofore, it was generally considered not favorable for oil production, although some gas had been found in various places. The play has extended east into the McAlester coal basin, and southeast toward the

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TABLE 1.—*Oil and Gas Production in Oklahoma*

Line Number	Field, *County*	Age in Years to End of 1934	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934
1	Allen[1], *Pontotoc*	21	3,000			3,000	34,367,718	4,223,355	3,065,168	
2	Bethel, *Seminole*	10		500		500	1,820,000	51,000	50,000	140
3	Billings, *Noble*	19	600		60	600	4,656,000	18,600	13,500	31.7
4	Bowlegs, *Seminole*	8	3,820			3,820	96,320,902	3,863,238	3,953,664	9,592
5	Brock, *Carter*	13	600			600	3,479,000	34,000	155,000	430
6	Burbank[2,3], *Osage, Kay*	14	22,500			22,500	184,744,000	3,552,000	3,352,000	9,100
7	Caldwell[4], *Grant*	6	30			30	176,000	13,000	8,600	20
8	Carr City, *Seminole*	7	1,060			1,060	20,811,000	2,753,000	1,998,000	4,890
9	Carter-Knox, *Grady, Stephens*	10	1,800			1,800	10,762,000	670,000	602,000	1,575
10	Chandler[5], *Lincoln*		1,160			1,160	2,323,312			
11	Cleveland[6], *Pawnee*	29	9,720			9,720	52,693,817	682,958	620,359	1,621
12	Crescent, *Logan*	2	1,280			1,280	1,539,992	100,857	1,324,855	3,660
13	Cromwell, *Seminole*	10	5,000			5,000	48,665,000	1,795,000	1,689,000	4,350
14	Cushing, *Creek*	23	23,528			23,528	319,479,767	4,553,270	4,537,210	12,919
15	Davenport, *Lincoln*	10	1,690			1,690	11,467,969	272,400	273,397	697
16	Deep Rock, *Payne*	10	520		80	600	2,036,429	y	y	
17	Dilworth, *Kay*	20	5,280		2,720	8,000	y	241,010	217,059	595
18	South Earlsboro, *Seminole*	5	300			300	7,248,000	604,000	401,000	800
19	Edmond[7], *Oklahoma*	4	260	80	0	340	116,892	1,384	95,212	325
20	Fairfax[8], *Osage*	9	3,480			3,480	3,735,125	72,990	2,556,716	11,090
21	Fitts, *Pontotoc*	1	1,720			1,720	323,584	0	323,584	1,923
22	Fox, *Carter*	19	1,110		420	1,530	11,300,000	300,000y	250,000y	650y
23	Garber, *Garfield*	19	3,840			3,840	46,983,559	948,078	857,869	2,283
24	Gessman, *Lincoln*	1	20			20	26,162	0	26,162	190
25	Glenn, *Creek*	28	14,720y			14,720				6,700y
26	Graham, *Carter*	17	2,520		220	2,740	23,300,000	800,000	700,000	1,800
27	Gray, *Pottawatomie*	3	180[3]			180	1,540,000	564,000	806,000	1,915
28	Grisso, *Pottawatomie*	1	80			80	21,800	0	21,800	490
29	Healdton, *Carter*	21	8,050			8,050	167,224,000	3,616,000	3,384,000	9,250
30	Hewitt, *Carter*	16	3,450			3,450	77,957,000	1,890,000	1,812,000	4,800
31	Hominy, *Osage*	15	300			300	1,753,343	38,281	35,256	86
32	East Hominy, *Osage*	14	450			450	1,829,373	45,705	36,199	86
33	Hubbard, or Retta, *Kay*	11	620			620	5,310,670	281,838	242,079	607
34	Josey, *Okfuskee*	12		270	10	280	4,598,154	167,171	154,064	400
35	Keokuk Falls, *Seminole*	2	600			600	562,911	187,064	375,064	1,006
36	Laffoon, *Lincoln*	2	x			x	94,000	16,000	78,000	200
37	Langston, *Logan*	1	160			160	73,000	0	73,000	275
38	Lincreek, *Lincoln-Creek*	19	160			160	488,860	222,416	194,349	497
39	East Little River, *Seminole*	7	640			640	14,954,780	404,932	263,950	723
40	Lucien, *Noble*	2	2,200			2,200	3,967,100	1,095,237	2,871,863	7,651
41	Marshall, *Logan*	8	700	240		940	13,065,485	3,287,967	1,886,663	727
42	Maud, *Pott.-Seminole*	6	1,440			1,440	10,092,000	559,000	443,000	1,020
43	Meeker, *Lincoln*	1	10			10	8,448	0	8,448	0
44	Naval Reserve, *Osage*	7	2,240	160	160	2,560	3,837,200	435,419	2,916,374	7,839
45	Newman, *Hughes*	11	x			x	91,142			12
46	Nicoma Park, *Oklahoma*	5	x			x	250,284	29,580	25,087	62
47	Norfolk, *Payne*	17	130	230		360	2,504,929			
48	West Norfolk, *Payne*	7	230			230	1,616,380			
49	Oklahoma City, *Oklahoma*	6					209,094			
50	Oklahoma City, *Oklahoma*	5	3,690			3,690	151,835,527	46,910,992	47,210,407	122,370
51	Oklahoma City, *Oklahoma*	6	6,250		200	6,450	80,998,535	16,050,329	13,237,036	30,111
52	Oklahoma City, *Oklahoma*	6	1,590			1,590	17,504,866		95,054	162
53	Oklahoma City, Total					11,730	250,548,022			
54	Otoe City, *Noble*	5	10			10	49,957	8,752	6,310	18.5
55	Otstott, *Kay*	17	3,300			3,300	3,244,543	249,158	227,361	598

[a] Footnotes to column headings and explanation of symbols are on page 249.

[1] Includes West Allen.

[2] South Burbank, included with Fairfax, below.

[3] Part of field under repressuring.

[4] Major portion of field is in Kansas.

[5] Includes West Chandler.

[6] Includes Lauderdale and North Terlton.

[7] Field discovered in 1930 and shut in until April 1934; Pressure "e" at —5400 datum.

[8] Includes South Burbank.

Ouachita Mountains. Geologists and lease men are active throughout the area.

Altus Wells.—A small gas well southwest of Altus, in Jackson County, sec. 10, T.1N., R.20W., was completed in November in an arkosic sand at about 1500 ft. Completion of a 300-bbl. well on the same lease since the end of the year may be the forerunner of an important development. This is the first production on the southwest flank of the Wichita Mountains, and has aroused general interest in a considerable area that previously was dormant.

Edmond Pool.—The Edmond pool was discovered in 1930, with a 300-bbl. well, in the "Wilcox" sand at 6700 ft., sec. 32, T.14N., R.3W. in Oklahoma County. The well was shut in until April, 1934. Three offset wells were completed in 1934, all of which were higher structurally than the discovery well. The south offset is about 400 ft. higher than the discovery well. At the close of the year, a fourth well ½ mile north was being completed. The wells have rated potentials ranging from 1000 bbl. of oil with 60 million cubic feet of gas, to 14,000 bbl. of oil with a low gas-oil ratio. The field emphasizes the great unconformity between the Pennsylvanian and Ordovician. In the present wells, the maximum structural relief on the Oswego lime, which is the lowest definite Pennsylvanian marker, is less than 50 ft., while the structural relief in the Ordovician is more than 400 feet.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age in Years to End of 1934	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934
56	Papoose, *Hughes, Okfuskee*	11	2,400			2,400	22,349,000	522,000	481,000	1,300
57	Pettit, *Osage*	15	380			380	3,623,575	56,400	48,288	122
58	Polo, *Noble*	1	130			130	103,148	0	103,148	900
59	Ponca City, *Kay*	24	1,670			1,670	5,756,700	133,709	118,874	309
60	North Ripley, *Payne*	7		90		90	1,110,000			
61	Robberson, *Garvin*	14	1,480		320	1,800	11,500,000*y*	539,000	465,000	1,200
62	Roff,[a] *Pontotoc*[9]	17							[9]	
63	Sasakwa, *Seminole*	7	560			560	6,717,658	730,761	353,900	
64	Sasakwa Townsite, *Seminole*	2	120			120	707,806	224,000	483,806	
65	Seminole City, *Seminole*	9	3,640			3,640	107,508,499	3,932,217	3,683,282	8,800
66	West Seminole, *Seminole*	5	180			180	6,332,000	1,216,000	2,196,000	2,527
67	Sholom Alechem, *Carter, Stephens*	11	4,180		220	4,400	28,800,000*y*	2,023,000	1,586,000	4,100
68	Tatums, *Carter*	8	2,200	0	0	2,200	11,600,000*y*	2,325,000	2,407,000	5,800
69	Thomas, *Kay*	11	140			140	5,280,000	76,512	60,995	145
70	Tonkawa, *Kay, Noble*	14	2,300	500		2,800	116,257,587	1,675,161	1,386,929	3,419
71	Vernon, *Kay*	11	920			920	2,353,504	176,502	178,266	518
72	Vines or Scott, *Murray*[10]	15	*x*			*x*	3,000*y*	1,000*y*	*x*	*x*
73	Wewoka, *Hughes, Seminole*	12	2,150			2,150	37,546,522	1,647,181	1,629,124	*x*
74	Wewoka Townsite, *Seminole*	Included with Wewoka								
75	Wheeler, *Carter*	19	540		160	700	1,100,000*y*	35,000*y*	37,000*y*	100*y*
76	Wilzetta, *Lincoln*	1	200			200	141,000	0	141,000	340
77	Braman, *Kay*	11	910	185		1,095	18,796,736	599,699	543,800	1,593

[9] Wells made 1 to 5 bbl. of very heavy asphaltic oil but none was ever sold.
[10] Hot air circulated in wells in order to pump heavy oil.

TABLE 1.—(*Continued*)

	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1934		At End of 1934				
Line Number	Per Acre to End of 1934^b	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas^c	Producing Gas Only	Total Producing
1	11,459			*x*	*x*	*x*									
2	3,640	182	5	*x*	*x*	*x*		52	0	*x*					30
3	7,760	155	4.5	*x*	*x*	*x*		60	0	0	1	7		3	10
4	25,215		43	*x*	*x*	*x*		354	0	*y*		223			223
5	5,798	*x*	3.6	*x*	*x*	*x*		139	0	0		121			121
6	8,388		4.6					2,204	3	28		1,980	*y*	*y*	1,980
7	5,867	978	20					2	0	0		1			1
8	19,633	785	51					113	0	*x*		96			96
9	5,980		10					214	1	4	10	158			158
10								67							
11	5,421		3					1,350				544		21	565
12	1,203	41.5	159	1,309*y*	183	1,126	*y*	23	14	0	0	21	*y*	2	23
13	9,733		15.5					490	1	14		280	*y*	*y*	490
14	13,579		6.4					3,512				2,005		64	2,069
15	6,786							228?							
16	3,380							48				10		1	11
17			5.4						1			116			116
18	24,160	965	40					30	0			22			22
19	344	*x*	81	40,280	0	40,280	*x*	5	3		0	3	2	0	5
20	1,073	18	*y*					119	98	0	14				
21	188		92					21	21	0	0	21			21
22	10,200		6	75,000*y*	4,500*y*	4,000*y*		142	0	0	6*y*	98		38	136
23	12,235	*x*	3.8					951				601		7	608
24	1,308		190					2	2	0	0	2	0	0	2
25			2.8*y*									2,450			2,450
26	8,500	190	6	46,000*y*	1,600*y*	1,400*y*		322	0	0	6	300		18	318
27	8,550	342	137					14		0		14			14
28	275	23	490					1	1	0	0	0	1	0	1
29	20,773							2,142	7	7	*x*	1,893			1,893
30	22,600		6					896	0	3	12*x*	794			794
31	5,844	106	7					37	0	0		12			12
32	4,065		2.8					65	1	0		30	1	0	31
33	8,565		17					75		5	7	35			35
34	17,030		14					33	0	0			29	1	30
35	938		72					15	9	0	0	15	0	0	15
36	*x*	*x*	200					2	1	0	0	2	0	0	2
37	456	45	90					3	3	0	0	3	0	0	3
38	3,553		83	7,816				20	0	7			6		6
39	23,367		10					87	0			63			63
40	1,800		144					55	38	0	2	53			53
41	13,900	331	25	12,000*y*	*x*	*x*	*x*	53	0	1	*y*	29		8	37
42	7,008	701	10					140	0	*x*	4	100			100
43	845							1	1	1		0			0
44	1,599	23	78	952	0	952		114	76	0	5	100		9	109
45	*x*	*x*	12					1	0	0	0	1	0	0	1
46	*x*	*x*	62					1	0	0	0	1	0	0	1
47	19,269							28				15		13	28
48	7,027							30				19		11	30
49								91			10	5		76	81
50	41,147	342	223	*y*	*y*	*y*	*y*	557	56	3	43	20	487	4	511
51	12,959		74	*y*	*y*	*y*	*y*	435	0		86	30	279	19	328
52	11,009		23					107	0		30	6	4	0	10
53								1,190							
54	4,995	208	18.5					1	0	0	0	1	0	0	0
55								122	*y*	*y*	*y*	*y*	*y*	*y*	*y*

South Burbank.—The discovery well in the South Burbank field was completed in March, 1934, with an initial production of 1300 bbl. from the Burbank sand at 2850 ft. This development created considerable interest in the sales of Osage Indian leases. By the end of the year, 78 wells had been completed with an initial production as high as 5000 bbl. Further development may prove that this field connects the Burbank and Fairfax fields.

Other Wells.—A number of other pools were discovered but none has promise at this time of becoming a major field. Perhaps the largest of these is the Polo field in T.22N., R.2W., Noble County, which was opened in July. Production is from the "Wilcox" sand at about 4200 ft. At the end of the year, 11 wells had been completed, with initial production ranging from 1200 to 2500 bbl. A well northwest of Langston in sec. 14, T.17N., R.1W., was completed in the first "Wilcox" sand for 225 bbl. at 4900 ft. Water was found in the second "Wilcox." Two offsets have been completed. It is possible this field may cover considerable area but unless more sand is found it will not be an important factor in the industry. The Wilzetta pool was discovered in February, with a well in sec. 35, T.12N., R.5E., producing from the Hunton lime at 4250 ft. The "Wilcox" sand was dry. Three offsets were completed during the year. The initial production after acidizing ranged from 500

TABLE 1.—(*Continued*)

	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1934		At End of 1934				
Line Number	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
56	9,312	931	12					267	0	*x*	*x*	96			96
57	?							32	0	4	3	18	0	0	18
58	793		100					9	9	0	0	9	0	0	9
59	3,445		7					128	0	2	27	43	0	0	43
60	12,333	445						9	0	*x*		4	4		9
61	7,700		6					273	0	5		200		15	215
62								4	0	4	0	0	0	0	0
63								50*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
64	5,900							6							
65	29,535		39					357	4	*x*		225			225
66	35,178	1,172	168					16	0	1	0	15			15
67	7,000*y*		13	15,000*y*				362	0	3		330		15	345
68	5,300	90	29	0	0	0	0	195	28	0	0	195	0	0	195
69	37,714							29	0	0	1	9	0	0	9
70	41,520	*x*	6.6	*x*	*x*	*x*	*x*	898	0	13	21	516		21	537
71	2,555							53	0	0	3	10			10
72	*x*	*x*	*x*	0	0	0	0	2	0	0	2	0	0	0	0
73	17,463							350							170
74															
75	2,000*y*		2	500*y*	0	0	0	100*y*	0	*x*		50*y*			50*y*
76	400	8	85	*x*	*x*	*x*	*x*	4	4	0	0	4	0	0	4
77	20,626	1,375	21.5	*x*	*x*	*x*	*x*	144	0	1	10	74		7	81

TABLE 1.—(*Continued*)

	Average Depth, Ft.		Oil Production Methods at End of 1934						Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1934				
			Number of Wells							Average at End of		Gravity A.P.I. at 60° F.				
Line Number	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas Lift	Air-Lift	Miscellaneous	Injection into Reservoir[d]	Initial	1933	1934	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1																
2	3,300	3,280		30										37		
3	2,100	2,000		7					x	x	x	42	41			P
4	4,300	4,100		223										40	0.3	
5	2,100			121								38	25	35	0.8	A
6	2,900			1,980										38		
7	4,785	4,779		1										40		M
8	4,205	4,180		96					e320	e135	e100			40	0.3	M
9	2,100			168								38	26	35		
10																
11	2,400			544								39	36			
12	6,210	6,180	21	1	1				e2,760	e2,700	e2,400	43.3	41.8	y	0.2	M
13	3,400			280										35		
14	Various			2,005								40	36			
15				All												
16	4,250	4,200		10										40		M
17	Various											42.7	38	40		P
18	4,225	4,200		22					e550	e370	e370			40	0.3	M
19	6,600		3	0	2	0	0		e2,900	e2,900	e2,829	52	38	39y		
20	2,800	2,750							900		800	42	38			
21	4,290	4,190	21	0	0	0	0		e1,920		e1,815	39.6	38.6	39.2	0.2	M
22	2,500	2,200		98					500–1,000			35	27	31		M
23	Various			601								42	36			
24	3,050		2	0	0	0	0									P
25	1,575	1,475		2,450										35		P
26	2,800	2,400		300					750			36	26	32		M
27	3,500	3,475		14					e1,440	e1,220				40		M
28	4,067	4,055	1											35		M
29	750–1,900			1,893								32	29	31		
30	1,500–3,000			794								36	31	34		
31	2,685	2,625		12								36	35	35.5		P
32	2,210	2,160		31								37.9	36.9	37.4	0	P
33				35								53.1	37.5			
34				29												P
35	4,113	4,085	15	0	0	0	0		e1,820	e1,715	e1,710	42	41.5			
36	4,275	4,190	0	2	0	0	0		e1,872					22.5		A
37	5,145	5,100	3	0	0	0	0							40		M
38	3,710	3,643	2	4	0	0	0		1,100y					40		
39			0	63	0	0	0					41	37			P
40	5,200	5,000	51	2					e2,200		e1,594			41.8	0.2	P
41	6,039	5,918	2	4	13	0	0		e1,950	x	x	40	36	36.3	0.3	M
42	4,140	4,130	0	100	0	0	0		e1,000y	50y	50y			39	0.35	M
43	5,461	5,455	0	0	0	0	0							32		
44	2,650	2,590	15	85	0	0	0		x	x	x	41.5	40.0	41	0	P
45	3,710	3,693	0	1	0	0	0		x	x	x					
46	6,250	6,157	1	0	0	0	0		x	x	x			39		P
47	3,500		0	15	0	0	0		x	x	x			40		M
48	3,625	3,590	2	17	0	0	0		x	x	x			39		M
49																
50	6,500	6,350	107	42	348		10		e2,600y	y	y			38	0.2	P
51	6,500	6,200	50	99	150		29		e2,600y	y	y			36	0.2	P
52	6,500	6,100	6	0	4	0	0		e2,600y	y	y	42	31	37	0.2	P
53																
54	3,314	3,286	0	1	0	0	0		x	x	x			41		
55	3,475	2,400	y	y	y	y	y		x	x	x			y		

to 1500 bbl. of oil and some water. An Earlsboro sand well in sec. 5, T.10N., R.4E. made 500 bbl. An offset was dry and a well ½ mile north had but little sand and was dry in the "Wilcox." A well in sec. 33, T.14N., R.4E. (Gessman pool) made about 250 bbl. from the Cleveland sand. This well was dry in the "Wilcox" sand and was plugged back. Two additional wells, with initial production of 450 and 750 bbl., respectively, and a dry hole were completed offsetting the discovery well. The Dill pool was opened in August by a well in sec. 2, T.11N., R.8E., Okfuskee County, with initial production of 700 from the Cromwell sand. One additional well was completed. Several other wildcats in the state produced oil but did not stimulate further immediate development.

Wildcats.—Two wildcats created much interest but at the end of the year looked disappointing. One was in Caddo County in sec. 34, T.10N., R.10W. Oil sand was found just above 10,000 ft. A test was disappointing and drilling continued to 11,230 ft. It was still in Pennsylvanian at the total depth, with indication that there might be 3000 ft. more before reaching pre-Pennsylvanian formations. In plugging back, trouble arose, and work was still going on at the well at the end of the year. It may make a 100-bbl. well. The other well, in sec. 19, T.11N.,

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1934						Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1934				
			Number of Wells							Average at End of		Gravity A.P.I. at 60° F.				
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas Lift	Air-Lift	Miscellaneous	Injection into Reservoir[d]	Initial	1933	1934	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
56	3,320	3,310	0	96	0	0	0		*x*	*x*	*x*			37	0.1	M
57				18												
58	4,900	4,823	9	0	0	0	0		*e*2,000			44	42			P
59			12	31	0	0	0					44.5	38.4			
60	4,259	4,199	0	9	0	0	0					40				M
61	1,400	1,300	0	200	0	0	0		600			33	25	28		M
62	500											22	19			A
63																
64			2	4												
65	4,150	4,100		225										40	0.3	
66	4,115	4,085	0	15	0	0	0		*e*500	*e*100	*e*100			40		M
67	3,300	2,900	0	330	0	0	0		760			35	27	32		M
68	2,400	2,250	0	195	0	0	0		500*y*	*x*	*x*	31	21	28		M
69			0	9	0	0	0		*x*	*x*	*x*	56.7	40.2			
70	4,216	1,819	0	516	0	0	0	32	*x*	*x*	*x*	44.2	41.8	39.8	0.2	M
71			1	9	0	0	0					42.3	36.0			
72	1,250	1,150	0	10	0	0	0					16	15			A
73	4,100	3,200		170												
74																
75	1,050	1,000	0	50*y*	0	0	0		300*y*			21	17	20*y*		M
76	4,290	4,240	0	4	0	0	0		*e*1,977		*e*1,970*y*	40	39	39.7	0	M
77	3,402	1,934	0	74	0	0	0	G	*x*	*x*	*x*	43	37	39.7	0.3	M

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1934		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average in Ft.	Structure[j]		Name	Depth of Hole, Ft.
1			Cromwell, Wilcox	Pen, Ord	S	Por	y	AF			
2			Cromwell	Pen	S	Por	20	A	8	Wilcox	4,385
3			Hoover	Pen	S	Por	50	A	10	Arbuckle	5,031
4			Wilcox or Simpson	Ord	S	Por		A	126	Wilcox or Simpson	4,913
5		1.25	Various sands	Pen	S	Por	x	AF	46	Ordovician Lime	3,000
6			Burbank	Pen	S	Por		ML	75	Granite	4,240
7			Wilcox	Ord	S	Por	6	A	2	Wilcox	4,785
8		2	Hunton, Wilcox	Sil, Ord	L, S	Por		A	13	Wilcox	4,210
9			Various sands	Per	S	15–20	15	Af	61	Lower Deese (Pen)	8,175
10			Wilcox	Ord	S	Por		A			
11			Cleveland, Bartlesville	Pen	S	Por				Arbuckle Lime	
12		0.38	Layton, Wilcox	Pen, Ord	S	23	W29 L26	Af	1	Second Wilcox	6,372
13			Cromwell	Pen	S	Por		Af	55	Wilcox	4,226
14			Numerous horizons	Pen, Ord	S-L	Por		Af		Granite	3,750
15			Prue	Pen	S	Por					
16			Wilcox, Bartlesville	Pen, Ord	S	Por	50	A	3	Arbuckle	4,542
17			Various	Per, Pen, Ord	S-SL	Por		A		Arbuckle	4,243
18		3	Wilcox	Ord	S	Por	25	A	4	Wilcox	4,225
19			Wilcox	Ord	S	Por		A	1	Wilcox	6,853
20			Burbank	Pen	S	20–25		ML	22		
21		1.25	Bromide (Wilcox)	Ord	LS	Por		AF	5	Bromide Form	4,290
22			Deese Form	Pen	S	30y		A	25	Dornick Hills	4,200
23			Various	Per, Pen, Ord	S-L	Por		AF		Granite	
24			Cleveland	Pen	S	Por		y		Wilcox	5,002
25			Glenn, Wilcox[11]	Pen, Ord	S	Por		ML		Arbuckle	2,964
26		1.0	Deese Form	Pen	S	28–30		A	40	Dornick Hills	5,108
27			Simpson (Wilcox)	Ord	S	Por	25	A	1	Simpson (Wilcox)	3,500
28			Hunton	Sil	L	x		A	1	Wilcox	4,860
29			Various	Pen, Ord	SL	Por		A		Arbuckle	
30			Hoxbar	Pen	S	15–20	50	Af	76	Arbuckle	
31			Burgess, Arbuckle	Pen, Ord	SL	x	S60 L50	A	8	Arbuckle	3,206
32			Bartlesville	Pen	S	Por	50	A	16	Arbuckle	2,857
33			Various	Pen, Ord	SL			AF	12	Arbuckle	3,761
34			Dutcher-Wilcox	Pen, Ord							
35			Misener	Mis	S	10	20	A	3	Wilcox	4,483
36			Wilcox	Ord	S	Por	89	A	0	Wilcox	4,267
37			Wilcox	Ord	S	Por	10	A	0	Wilcox	5,246
38			Wilcox	Ord	S	Por		A	6	Arbuckle	4,023
39			Cromwell-Wilcox	Pen-Ord	S	Por		A	24	Wilcox	4,754
40			Wilcox[12]	Ord	S	Por		A	5	Wilcox	5,500
41	1,195	0.6	Various	Pen, Ord	S	Por	116.5	AF	16	Arbuckle	6,608
42			Misener-Hunton	Mis, Sil	SL	Por	10	A	33	Wilcox	4,330
43			Wilcox	Ord	S	Por	6			2nd Wilcox	5,561
44	1,400	1.6	Burbank	Pen	S	13–33	70	ML		Wilcox	2,975
45			Lyons	Pen	S	Por	17	y	2	Lyons	3,710
46			Trosper	Pen	S	Por	10	ML	3	Wilcox	6,904
47			Various	Pen, Ord	SL	Por		A		Wilcox	3,509
48			Various	Pen, Mis, Ord	SL	Por		A		Tyner	3,705
49	1,120	0.8	Various	Pen	S	Por		A			
50	1,180	0.8	Wilcox	Ord	S	21	120	AF	14		

[11] Wilcox production is of minor importance and is limited to two local anticlines.
[12] One well producing from Oswego Lime and one from Misener sand.

R.1E., in Oklahoma County, showed oil in the Hunton lime at 6028 ft. and was dry in the "Wilcox" sand at 6525 ft. It was plugged back to the Hunton, but looked like a noncommercial well at the end of the year.

Lucien Field.—The Lucien field, in Noble County, continued the trend of development that it showed at the end of 1933. There were 52 wells, each in the center of a 40-acre tract, producing with a rated potential of about 115,000 bbl. In December, a well one mile east of production on the south end of Lucien was completed, making 600 bbl. from either the Misener or Viola. Production in the Lucien pool is from the "Wilcox" series.

Crescent Pool.—The Crescent pool, in T.17N., R.4W. practically completed development during the year. There were 23 wells in the field, having a rated potential of about 75,000 bbl. Spacing is generally one well in the center of a 40-acre tract. The field gained notoriety during the year when Eason Oil Co. obtained a court decision permitting it to drill on a 10-acre spacing contrary to the plan of development approved by the Administrator for the Petroleum Industry. This

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1934		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average in Ft.	Structure[j]		Name	Depth of Hole, Ft.
51	1,160	0.7	Lower Simpson	Ord	S	12	140	AF	8		
52	1,150	0.7	Arbuckle	Cam, Ord	L	Cav		AF	7	Arbuckle	7,138
53											
54			Layton	Pen	S	Por	24	A	4	Wilcox	4,675
55									11	Arbuckle	
56		1.0	Papoose (Cromwell)	Pen	S	Por	10	A		Wilcox	
57										Arbuckle	
58			Wilcox	Ord	S	Por	45	A	1	2nd Wilcox	4,919
59								A	46	Arbuckle	
60			Wilcox	Ord	S	Por		A	3	Wilcox	4,590
61		1.0		Per, Ord	SL	Por		A	6	Pre-Cambrian	1,745
62			Ada Form	Pen	LS	Por	35		4		600
63			Cromwell-Wilcox	Pen, Ord	S	Por		AF	17	Wilcox	4,300
64			Wilcox	Ord	S	Por		AF			
65			Wilcox (Simpson)	Ord	S	Por		A	142	2nd Wilcox	4,860
66		4.8	Wilcox	Ord	S	Por	30	A	2	Wilcox	
67			Deese Form	Pen	S	Por		A	54	Dornick Hills	5,115
68			Deese-Dornick Hills	Pen	S	Por	60	AMU	35	Dornick Hills	4,250
69			Various	Pen, Mis, Ord	S-L	Por		AF	25	Arbuckle	
70	1,335	3.13	Various	Pen-Ord	S	Por		Af	55	Arbuckle	4,415
71								A	8	Arbuckle	
72			Simpson	Ord	S	Por		A	1	Simpson	1,251
73			Cromwell-Hunton Wilcox	Pen, Sil, Ord	SL	Por		A	98	Wilcox	4,200
74											
75			Pontotoc	Pen	S	Por		A	15	Pennsylvania	3,900
76		3.0	Hunton	Sil	L	x		A		Wilcox	4,520
77	1,440	4.7	Various	Pen-Ord	SL	Por		A	15	Arbuckle	3,553

decision may cause a redevelopment of the field on a 10-acre spacing, resulting ultimately in one well to each 8 acres.

Greater Seminole.—In the Greater Seminole area some development continued in the south part of the St. Louis district. Most of the production was from the upper Simpson dolomite, although "Wilcox" sand production was found near the end of the year in sec. 6, T.6N., R.5E. A productive "Wilcox" spot was found at the south end of the Fish pool in sec. 31, T.7N., R.8E. In several places in the Seminole area there is known to be undeveloped Hunton lime production, especially in the southwestern part. The wells are not large and production is erratic, but generally they respond to acid treatment. This Hunton production may be the object of much of the drilling activity in the area in 1935.

Oklahoma City Field.—The Oklahoma City field had but little additional development. During the year, proration restrictions were removed from wells producing from the Arbuckle and lower Simpson. Of the 550 "Wilcox" wells, only about one-fourth were flowing naturally at the end of the year. The present potential of the "Wilcox" sand wells is only 935,000 bbl., compared to 3,200,000 at the beginning of 1934. It is probable that the present rated potential is considerably higher than could be demonstrated by an actual test of all wells. This does not mean, however, that the Oklahoma City field will not continue to be an important producer of oil for several years. Its present allowed production is 125,000 bbl. a day from all zones.

General.—Development in the northeastern part of the state in the shallow producing areas was more active than it has been during the past five or six years. Interest was again being developed in repressuring, in study of possible favorable water-flooding prospects, especially in areas that responded to acid treatment. The state produced approximately 178,000,000 bbl. in 1934, which is almost the same as production in 1933. There were 1717 wells[1] completed, of which 27 per cent were dry holes and 5 per cent gas wells. In 1933, there were about 1100 completions. Wildcat wells were more numerous and more successful than in 1933. Proration by the Corporation Commission was generally successful. The price level of crude oil was maintained throughout the year, although there was a short period in the early fall when the price structure was weak.

Outlook.—In 1935, most of the production development will be in the Fitts and Edmond fields. Wildcatting probably will be more intensive than in 1934 and no doubt will result in the discovery of several new fields. The general optimism at the beginning of 1934 waned in the middle of the year but was revived, and 1935 started out with a more favorable outlook than for several years.

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[1] *Oil & Gas Jnl.* (Jan. 28, 1935).

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Oil and Gas Development in Pennsylvania, 1934

By S. H. Cathcart*

(New York Meeting, February, 1935)

Price, production and drilling operations exceeded any year since 1930. A top price for crude of $2.55 was maintained from May 1 to November 6 and increased activity about coincides with that period. The average crude price for the year was: Bradford, $2.46; Kane-Butler, $2.34; Southwest Pennsylvania, $2.13.

Production for the year exceeded 15 million barrels, an increase of about 2 million barrels over 1933. That this increase was more than justified by market demand is indicated by a reduction of 892,000 bbl. in stocks for the year.

Two classes of data appear on Table 1, which are differentiated by footnote references. Where possible the figures were obtained from individuals and companies that, from long acquaintance and varied contacts, are most capable of supplying an estimate where an estimate is necessary. The remaining data represent a rather careful compilation from all available published records (see p. 378).

Drilling operations and production as summarized by the *Oil City Derrick* are as shown on Table 2.

Table 1.—*Oil and Gas Production in Pennsylvania*

Line Number	Field, *County*	Age, Years to End of 1934[1–2]
1	*Allegheny*	15 to 56
2	*Armstrong*	14 to 69
3	*Beaver*	37 to 74
4	*Butler*	21 to 66
5	*Clarion*	46 to 65
6	*Crawford*	12 to 75
7	*Elk*	9 to 52
8	*Erie*	75
9	*Fayette*	13 to 46
10	*Forest*	50 to 70
11	*Greene*	8 to 70
12	*Indiana*	40 to 51
13	*Jefferson*	19 to 52
14	*Lawrence*	24 to 54
15	*McKean*	19 to 71
16	Bradford, *McKean*	
17	*Mercer*	13 to 34
18	*Potter*	1 to y
19	East Fork, *Potter*	2
20	Ellisburg, *Potter*	1
21	Genesee, *Potter*	2
22	Harrison, *Potter*	1
23	Hebron, *Potter*	3
24	*Somerset*	4
25	Farmington, *Tioga*	4
26	Gaines, *Tioga*	37
27	*Venango*	47 to 75
28	*Warren*	13 to 74
29	Sheffield Township, *Warren*	54
30	*Washington*	32 to 52
31	*Westmoreland*	14 to 56
32	Total	

[1] For county, range of age of pools in years since discovery is indicated.
[2] Data compiled by Pennsylvania Geological Survey.

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Practically all drilling in Bradford field, where activity centered, was in proven territory and for repressuring purposes.

OUTSTANDING ACTIVITIES IN 1934

There was no significant discovery during 1934. The "shallow" sand fields of western Pennsylvania were not appreciably extended either laterally or vertically and only one new pool was indicated in the "deep"-sand gas area in the northern part of the state. The outstanding activities of the year were: (1) experimental water-flooding and gas and air

TABLE 1.—(*Continued*)

Line Number	Area Proved, Acres				Total Oil Production, Bbl.				Average Oil Production, Bbl.		
	Oil	Oil and Gas[a]	Gas	Total	To End of 1933 [2,4]	During 1933 [3]	During 1934	Daily Average during Nov., 1934	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934
1	66,*xxx*[2]	*x*	11*x*,*xxx*[2]	17*x*,*xxx*	33,178,231[5]	254,527	*y*	*y*	*x*	*x*	*y*
2	15,*xxx*[2]	*x*	28*x*,*xxx*[2]	29*x*,*xxx*	297,386	22,576	*y*	*y*	*x*	*x*	*y*
3	20,*xxx*	*x*	25,*xxx*	45,*xxx*	1,058,544[6]	43,006	46,*yyy*	1*yy*	1,*xxx*	1*xx*	0.1
4	66,*xxx*	*x*	6*x*,*xxx*[2]	12*x*,*xxx*	8,937,478	482,912	*y*	*y*	650	*x*	*y*
5	20,*xxx*[2]	*x*	181,*xxx*	201,*xxx*	2,505,160	144,053	134,*yyy*		*x*	*x*	*y*
6	6,*xxx*	*x*	1,*xxx*[2]	7,*xxx*	996,900	100,483	*y*	*y*	*x*	*x*	*y*
7	12,427	*x*	99,*xxx*	111,*xxx*	1,200,035	74,118	*y*	*y*	983	26	*y*
8			3,*xxx*	3,*xxx*							
9		*x*	11,*xxx*[2]	11,*xxx*							
10	22,*xxx*	*x*	19,*xxx*[2]	41,*xxx*	1,396,121	93,239	81,*xxx*	22*x*	*x*	*x*	*y*
11	21,*xxx*[2]	*x*	25*x*,*xxx*[2]	27*x*,*xxx*	10,891,533	169,324	*y*	*y*	8*xx*	*x*	*y*
12			64,*xxx*	64,*xxx*							*y*
13		2,6*xx*	105,*xxx*	108,*xxx*	113,835	4,832	5,960	16	*x*	*x*	*y*
14	15,*xxx*	*x*	8,*xxx*	23,*xxx*	324,735[6]	18,092	20,*yyy*	5*y*	3*xx*	2*x*	*y*.1
15	80,*xxx*	*x*	76,*xxx*	156,*xxx*	69,603,942	*y*	*y*	*y*	*x*	*x*	*y*
16	75,258			75,258	292,177,*xxx*	10,129,*xxx*	11,897,700	31,081	40*xx*	10*x*	*y*
17	7,*xxx*[2]	*x*	16,*xxx*[2]	23,*xxx*	192,490	13,596	*y*	*y*	*x*	*x*	*y*
18	1,280[2]	*x*	35,*xxx*[2]	36,*xxx*	114,959	8,345	*y*	*y*	*x*	*x*	*y*
19			200	200							
20			1,600	1,600							
21			500	500							
22			*xxx*	*xxx*							
23			4,*xxx*	4,*xxx*							
24			6*xx*[2]	6*xx*							
25			7,000	7,000							
26	2*xx*[2]			2*xx*	47*x*,*xxx*[7]	5,5*xx*	4,8*xx*	13	1,5*xx*		*y*
27	84,*xxx*	*x*	44,*xxx*	128,*xxx*	15,533,037	931,032	*y*	*y*	*x*	*x*	*y*
28	49,*xxx*			53,*xxx*	4,503,110	300,687	*y*	*y*	*x*	*x*	*y*
29	6,211	6,022	4,473	16,706							
30	65,*xxx*[2]	*x*	19*x*,*xxx*[2]	25*x*,*xxx*	79,287,302[5]	416,709	*y*	*y*	*x*	*x*	*y*
31	8*xx*[2]	*x*	95,*xxx*[2]	95,*xxx*	2,*xxx*	302	*y*	*y*	*x*	*x*	*y*
32	55*x*,*xxx*[16]	*x*	1,6*xx*,*xxx*[16]	2,1*xx*,*xxx*[16]	89*x*,*xxx*,*xxx*[8]	12,544,179	15,263,950[9]	40,351	Text	Text	*y*

[a] Footnotes for column heads and explanation of symbols are on page 249.

[3] Chiefly from Pennsylvania Bureau of Statistics reports.

[4] Figures for Allegheny, Greene, Tioga and Washington counties indicate all years except 1907–1920 when only total production for Pennsylvania was reported. Remaining figures are for years 1921–1933, as previous to 1921 production for these counties was reported in larger than county units and cannot be apportioned. Bradford field is total production for that part of the field in Pennsylvania.

[5] From 1891–1906 the McDonald pool produced 41,025,000 bbl., of which 30,000,000 is here assigned to Washington and the remainder to Allegheny County.

[6] From 1889–1906 Beaver and Lawrence counties produced 9,590,642 bbl., which cannot be apportioned between them. It has been estimated that the total production of Beaver County is 30,000,000, and of Lawrence County 4,000,000 barrels.

[7] Total production of field to Dec. 31, 1934 from company records.

[8] Total for Pennsylvania to Dec. 31, 1934.

[9] *Oil City Derrick.*

[16] Figure probably is large. Two classes of estimate are included. All figures with index number 2 represent area as measured on the oil and gas fields maps of western Pennsylvania published by the Pennsylvania Geological Survey in 1932 the remaining figures represent estimates submitted by individuals or companies operating in the respective areas. The map figures are in many instances known to be excessive.

repressuring in the area south of Bradford and (2) "deep" tests of the Oriskany sand.

Progress in Adaptation of Secondary Recovery Practice.—An increasing interest in the possibilities of water-flooding in the area south of Bradford was indicated by attempts to purchase unimproved acreage for experimental flooding and to take options on acreage for core-drill tests. Some acreage was purchased and some new flooding tests were begun during the year. An experimental water-flood test in the Clarendon sand, Warren County, has indicated a locally favorable result. The locality was carefully selected and it is not considered that the expectation of comparable results in all parts of the field is justified.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
						During 1934		At End of 1934				
	To End of 1933 [2,10]	During 1933 [3]	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[6]	Producing Gas Only	Total Producing
1	105,*xxx*	2,638	*y*	*y*	*y*	*y*	*y*	*y*	1,549[14]	*y*	462[14]	2,011[14]
2	167,*xxx*	7,059	*y*	*y*	*y*	*y*	*y*	*y*	261[14]	*y*	2,144[14]	2,405[14]
3	4,*xxx*	188	58	*y*	1,9*xx*[12] 4*xx*	7[13]	2*y*[13]	*y*	77*y*	*y*	30	80*y*
4	44,*xxx*	1,675	*y*	*y*	*y*	*y*	*y*	0	5,484[14]	*y*	420[14]	5,904[14]
5	149,*xxx*	8,040	8,186	*y*	*y*	*y*	*y*	*y*	2,387	*y*	3,9*yy*	6,2*yy*
6					*y*	2*y*	*y*	*y*	8*yy*	*y*	*y*	8*yy*
7	70,*xxx*	3,909	3,652	*y*	*y*	*y*	*y*	1*yy*[13]	1*yy*	*y*	1,3*yy*	1,4*yy*
8	5*xx*	6	*y*	*y*	*y*	*y*	*y*	*y*			53[14]	53[14]
9	30,*xxx*	1,388	*y*	*y*	*y*	*y*	*y*	*y*		*y*	178[14]	178[14]
10	13,*xxx*	545	*y*	*y*	*y*	15	55	*y*		1,491		1,491
11	197,*xxx*	9,833	*y*	*y*	*y*	*y*	*y*	*y*	754[14]	*y*	1,639[14]	2,393[14]
12	45,*xxx*[7]	1,181	1,500	6	450	4	20	*y*			250	250
13	119,*xxx*	6,147	8,647	*y*	*y*	*y*	*y*	*y*		16*x*	2,28*y*	2,44*x*
14	1,6*xx*	16	20	*y*	1,8*xx*[12] 1*xx*	10[13]	1*y*[13]	*y*	7*yy*	*y*	15	7*yy*
15	51,*xxx*	2,957	2,626	*y*	*y*	*y*	*y*	*y*	*y*	*y*	1,76*x*	*y*
16	*y*	2,255	*y*	*y*	32,*xxx*	1,366	*y*	*y*	31,*xxx*			31,*xxx*
17	4,*xxx*	112	*y*	*y*	*y*	*y*	*y*		381[14]	*y*	82[14]	463
18	24,*xxx*	3,546	*y*	*y*	*y*	33	*y*	*y*	251[14]		1,031[14]	1,282
19	79[7]	18	62	3	2	1					2	2
20	448[7]	0	448	2	7	5		1			6	6
21	*y*	*y*	*y*	*y*	2	2	1				*y*	*y*
22	0	0	0	0	1	1						
23	19,218[7]	3,408	15,361	65	30	22	1				29	29
24	3,*xxx*	2,066	*y*	*y*	1*y*						3	3
25	24,913[7]	7,899	10,258	*y*	44	3	3				41	41
26					1*xx*			*y*	52			52
27	56,*xxx*	2,272	1,894	*y*	*y*	5*y*	*y*	*y*	24,428[14]	*y*	85*y*	25,27*y*[14]
28	11,*xxx*	478	*y*	3	*y*	*y*	*y*	*y*	6,388[14]			6,699[14]
29			*y*	3	1,198	*y*	*y*	*y*	621	147	164	932
30	155,*xxx*	6,616	*y*	*y*	*y*	*y*	*y*	*y*	1,746[14]	*y*	911[14]	2,657[14]
31	82,*xxx*	2,859	*y*	*y*	*y*	*y*	*y*	*y*		*y*	707[14]	707[14]
32	5,407,149[11]	71,528	*y*	*y*	20*x*,*xxx*[2]	1,554	*y*	*y*	80,548[14]		16,460[14]	97,008[14]

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[10] Estimated total for 1920–1933. Pennsylvania Bureau of Statistics figures by counties 1920–1927 and 1931–1933. Production 1928–1930 interpolated.

[11] Total gas marketed 1882–1933. Production in cubic feet recorded 1906–1933 is 3,096,083 M.M. From 1882 to 1905 production was recorded in terms of value in dollars. Arnold and Kemnitzer estimate volume 1882–1900 as 1,611,066 M.M. cu. ft. We estimate volume 1901–1905 as 700 M.M.M. The amount of gas wasted in the early days of the Pennsylvania fields can hardly be estimated but it probably is as great as the amount marketed.

[12] Upper figures apply to oil, lower to gas.

[13] Apply to oil only.

[14] Figure is for 1933 from Pennsylvania Bureau of Statistics.

Water-flooding has been attempted in scattered localities in the Venango sands but to date the practice has not been successful. In at least two instances sand conditions were studied and the tests carefully conducted, but water broke through without appreciable increase in oil recovery. In most other instances tests were less efficient, either from the standpoint of equipment or operation, and the results are less conclusive. There is now considerable interest in the deeper sands and it is expected that some deeper drilling and further testing will be done during 1935.

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1934				Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1934					Character of Gas, Approx. Average during 1934	
			Number of Wells				Initial	Average at End of		Gravity A.P.I. at 60°F.						
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Air-lift	Injection into Reservoir[d] [15]		1933	1934	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
1	2,100	2,050		All			*y*	Vac	Vac	454	417	*y*	014	P	1,3*xx*	400
2	*y*	*y*		All			*y*	*y*	*y*	*y*	*y*	*y*	*y*	P	*y*	*y*
3	900 1,350	875 1,300		All		G47 A37	B2*xx* H5*xx*	Vac[12] 54	Vac[12] 50	*y*	*y*	4*y*	01*y*	P	*y*	400
4	1,100 to 2,400			All			*y*	Atm or Vac	Atm or Vac	469	410	430	012	P	1,5*xx*	20
5	*y*[12] 2,04*y*	*y*		All			*y*	Vac	Vac	*y*	*y*	*y*	*y*	P	*y*	400
6	980	800		All		GA	*y*	Vac to 10	Vac to 10	*y*	*y*	*y*	0*y*	P	*y*	*y*
7	2,402[13]	2,340[13]		All			*y*	*y*	*y*	460	430	445	00	P	1,2*xx*	15
8	*y*	*y*					*y*	*y*	*y*						*y*	*y*
9	2,5*xx*	1,5*xx*					*y*	*y*	*y*						*y*	*y*
10	700[13] & 1,500	*y*		All		W 700	*y*	*y*	*y*	470	430	*y*	*y*	P	1,3*x*	40
11	2,200	2,150		All			*y*	Vac	Vac	404	404		008	P	*y*	400
12	2,8*yy*	2,1*yy*					*y*	*y*	*y*						1,105	*y*
13	2,58*y*	*y*					*y*	*y*	*y*	*y*	*y*	*y*	*y*	P	*y*	*y*
14	690[12] 950	650[12] 900		All			2*xx*[12] 250	Vac[12] 54	Vac[12] 50	*y*	*y*	4*y*	01*y*	P	*y*	*y*
15	*y*[12] 2,280			All			*y*	*y*	*y*	465	404	*y*	*y*	P	*y*	*y*
16	1,540	1,500		All		W	600	30	*y*	485	434	*y*	014	P	1,150	25
17	*y*	*y*		All			*y*	*y*	*y*	325	325		009	P	*y*	*y*
18	*y*	*y*		All			*y*	*y*	*y*	*y*	*y*	*y*	*y*	P	*y*	*y*
19	6,220	6,200					*y*	*y*	*y*						*y*	00
20	5,160	5,160					2,130	2,130	2,040						*y*	00
21	4,850	4,850					2,025	2,025	2,025						*y*	00
22	4,750	4,750					2,140		2,140						*y*	00
23	5,215	5,200					2,160	1,850	1,075						1,020	00
24	2,6*yy*	2,5*yy*					7*yy*	*y*	*y*						*y*	*y*
25	4,050	4,040					1,650	900	450						1,030	00
26	1,000	982		All			Low	*y*	*y*	*y*	*y*	440	*y*	P		
27	420–950 1,97*x*[12]	400–900 *y*[12]		All			*y*	*y*	Vac to 5	415	317	*y*	011	P	1,3*xx*	400
28	900 & 1,500	350[13] & 1,000	2	Rest	4*y*	GA 1*xx* W40	600	*y*	*y*	*y*	*y*	422	015	P		200
29	1,776	1,700		All			*y*	*y*	61						1,250	012
30	2,200	2,150		All			*y*	Vac	Vac	520	432	*y*	01*y*	P	1,4*xx*	400
31	*y*	*y*					*y*	*y*	*y*	*y*	*y*	*y*	*y*	P	*y*	*y*
32						GA W				520	317	*y*		P		

[15] Number of wells producing by air or gas repressuring.

Although water-flooding has not yet been proved effective in the middle or "broken sand" district, these sands have responded rather favorably to air and gas repressuring at some localities and repressuring practice was considerably extended in this district during 1934.

Oriskany Sand Gas Fields of Northern Pennsylvania and Exploratory "Deep" Sand Developments.—Since the discovery of gas wells of large volume in the Oriskany sand of Tioga County in 1930, and in Potter County in 1931, there has been a live interest in the possibilities of the "deep" sand zones. Six Oriskany fields have been discovered in Pennsylvania, one in Tioga County and 5 in Potter County.

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
1	Fig. 1	MissL DevU	S	18.0	22	AMC	x	y	5,575
2	Fig. 1	MissL DevU	S	y	y	AMC	x	y	y
3	Text	MissL DevU	S	18.0	10^{12} 40	SAML	$1,xxx^{12}$ $4xx$	Chemung	3,200
4	Text	MissL DevU	S	12 to 15	25 to 35	AMC	x	Oriskany	4,857
5	Fig. 1	MissL DevU	S	13	14	AMC	x	y	y
6	Venango 3d	MissL DevU	S, cgl.	10 to 25	40	MLC	x	Queenston Sh	4,619
7	Kane (Fig. 1)	DevU	S	12.0	38	AMC	x	Queenston Sh	7,930
8	Text	DevU	S & H	y	y	AMC	x	Trenton	4,450
9	Fig. 1	MissL DevU	S	y	y	AMC	x	5,070 ft. below Big Injun	6,020
10	Text	DevU	S	17.0	20	AMC	x	Salina	5,252
11	Fig. 1	Pa DevU	S	19.0	20	AMC	x	y	y
12	Fig. 1	MissL DevM	S	y	$2x$	AMC	450	?	7,002
13	Fig. 1	MissL DevU	S	y	y	AMC	x	Salina	8,220
14	Text	MissL	S	16.5	20^{12} 40	AMC	$5xx^{12}$ $1xx$	Helderberg?	4,767
15	Fig. 1	DevU	S	16	20	AMC	1,398	Medina (Red)	5,820
16	Bradford 3d	DevU	S	12.5	40	A	y	Medina (Red)	5,820
17	Fig. 1	MissL DevU	S	15.0	14.0	AMC	x	Oriskany	3,225
18	Fig. 1	DevL & U	S	y	y	AMC	x	Salina	5,561
19	Oriskany	DevL	S	y	20	A	0	150 ft. below Oriskany	6,437
20	Oriskany	DevL	S	y	x	AF	1	Oriskany	5,160
21	Oriskany	DevL	S	y	x	AF	1	Oriskany	4,850
22	Oriskany	DevL	S	y	x	AF	0	Oriskany	4,750
23	Oriskany	DevL	S	9 to 10	15	AF	12	Salina	5,561
24	Text	DevU	S	y	$1y$	y	$1y$	Portage	4,596
25	Oriskany	DevL	S	4 to 12	50	AF	40	Vernon Sh	7,148
26	Atwell & Blossburg	DevU	S & H	y	y	T	x	y	y
27	Text	MissL DevU	S, Cgl.	4 to 25	10 to 40	MLC	x	Queenston Sh	4,619
28	Text	DevU	S, Cgl.	4 to 25	10 to 30	AMC	x	Queenston Sh	5,818
29	Cooper	DevU	S		40		55.0	Niagara Ls	5,288
30	Fig. 1	MissL DevU	S	18.5	22	AMC	x	978 ft. below Oriskany	7,248
31	Fig. 1	MissL DevL & U	S	y	y	AMC	x	Salina	7,756
32		Pen to DevL					$4x,xxx^{2}$	Trenton	

The volume of gas marketed from the Farmington and Hebron fields, the discovery fields of Tioga and Potter counties, increased substantially in 1934. There was little drilling activity in Farmington field, but in Hebron field 22 wells were completed, 19 of which were successful, and 3 of which got salt water. The total initial rating of the 19 new wells is about 277 million cubic feet. Developments of the year extended the proven area of Hebron field about 2½ miles to the southwest along the axis of the dome and showed that several isolated wells 5 miles along the axis to the northeast in the vicinity of Ellisburg are separated from Hebron field by salt water.

Table 2.—*Summary of Drilling Operations and Production in Pennsylvania*, 1934

Fields	Depth, Ft.				Production, Bbl.		
					Initial		Tota
	Completed	Dry	Gas	Oil	Total	Average	
Bradford	1,336	0	1	1,335	2,316	1.77	11,897,700
Venango-Clarion	79	6	9	64	63	0.99	2,405,850
Butler-Armstrong	25	6	3	16	37	2.31	
Southwest Pennsylvania	114	24	48	42	782	18.62	960,400
Total	1,554	36	61	1,457	3,243	2.22	15,263,950

Eight exploratory wells were drilled to the Oriskany (Table 3). Only one of these, the Andrew Schofield No. 1, in Harrison township, northeast Potter County, was successful in indicating a new field. The McKean and Cameron County wells and a well in eastern Potter County found no sand present at the Oriskany horizon. The Lawrence and Butler County wells are 30 miles from the nearest Oriskany well in Pennsylvania. The Butler County well reported a show of oil and gas, the other nothing in the Oriskany sand.

An interest, as yet passive, has developed in the "deep" sand possibilities of northwestern Pennsylvania. Consideration is prompted by the presence of Oriskany gas fields in northern Pennsylvania and of Oriskany and Medina gas fields in New York, by the discovery of oil in the Oriskany in West Virginia, and by the stratigraphic favorability which the area offers for exploration of the "deep" sands. A number of wells, widely scattered, none of which are recent, have shown the presence of capable sand at the Oriskany and Medina horizons but none have been commercially productive. The presence of closed structure has not been demonstrated.

TABLE 3.—*Deep Wells Drilled in Oriskany Sand of Northern Pennsylvania in* 1934

Well	County	Township	Depth to Oriskany, Ft.	Total Depth, Ft.	Result
Andrew Schofield No. 1	Potter	Harrison	4745	4754	18 mil.
W. B. Bennett No. 1	Potter	Ulysses	5231-?	5552	Dry
Geo. Doty No. 1	Potter	Hector	Onon. 5492 no sand	5658	Dry
C. Campbell No. 1	Bradford	Ridgebury	4455-92	4512	Dry
M. Zerby No. 1	McKean	Liberty	Onon. 4705 no sand show gas 4847	5153	Dry
Emporium First Nat. Bank No. 1.	Cameron	Shippen	Onon. 4865 no sand	4992	Dry
J. Scott Munnell No. 1	Lawrence	Slippery Rock	4635	4767	
Lehigh Portland Cement Co. No. 1.	Butler	Muddy Creek	4809	Dr. 4888 1-30-35	Show oil and gas

OIL RESERVE

An estimate of the potential oil reserve and of the oil recoverable by present methods was made by the Pennsylvania Grade Crude Oil Association for the Cole Congressional Oil Investigating Committee. In making this estimate the Pennsylvania industry pooled its entire resources in data and experience. The result is meant to be a conservative estimate and is believed to be as authoritative as any estimate on Pennsylvania could be at this time.

As the data on which to base an estimate are much more abundant in Bradford field than elsewhere, the producing area was divided for consideration into two districts: (1) Bradford field and (2) the remainder of the state.

Bradford Field (Pennsylvania)

Oil in Place before Water-flooding.—A great deal of core drilling has been done in Bradford field in the past 10 years and very detailed core records have been kept. Practically all of these records were made available. The wells that were cored are scattered throughout all parts of the field and it is possible, therefore, by grouping core records to divide the field into zones according to the barrels per acre value shown by core analysis and to measure the area of the zones by the planimeter.

Using the formula, acres × barrels per acre = barrels of oil in place, the result is as shown in Table 4. Note that this estimate refers to the oil content of the sand after production by usual methods, but before water-flooding. It antedates the present in that part of the above acreage has now been water-flooded and part is in process of being water-flooded.

Reserves Considered Recoverable by Present Commercial Practice.—To arrive at the figures listed in Table 5, the areas considered as watered out and the areas being flooded were outlined on the "zoned" map from which Table 4 was prepared. A planimeter was then used to determine the number of acres that remain to be flooded in each zone or class of acreage, with the results shown in Table 5.

TABLE 4.—*Estimate of Oil in Place after First Drilling and before Water-flooding*

Acres	Barrels per Acre	Barrels in Place
795	8,000	6,360,000
8,820	9,000	79,380,000
20,422	10,000–11,000	214,431,000
26,031	12,000–14,000	338,403,000
19,200	15,000–16,000	297,600,000
75,268	12,200 (weighted average)	936,174,000

TABLE 5.—*Estimate of Oil Content of Unflooded Area January* 1, 1934

Acreage Remaining for Development	Class of Acreage, Bbl. per Acre	Oil Remaining in Unflooded Acreage, Bbl.
532	8,000	4,256,000
8,140	9,000	73,260,000
20,422	10,000–11,000	214,431,000
20,971	12,000–14,000	272,623,000
12,141	15,000–16,000	188,185,000
62,206	12,000	752,755,000

Flooding practice to date has recovered about 40 per cent of the oil contained in the sand. Using this factor, the amount of oil recoverable from the 62,206 undeveloped acres by the use of present flooding methods is 301,102,000 bbl. To this must be added the recoverable oil remaining in areas now undergoing flood. This is estimated to be equivalent to 1500 acres at a weighted average recovery of 2033 bbl. per acre, or 3,050,000 bbl. This indicates a probable total of 304,152,000 bbl. of oil in Bradford field (Pennsylvania) Jan. 1, 1934, recoverable by present commercial practice.

To Jan. 1, 1934, Bradford field (Pa.) had produced about 292,176,825 bbl., and was still capable of producing 304,152,000 bbl. by present methods, after which something like 459,500,000 bbl. would still be retained in the reservoir. For the year 1934 this field ranked fourteenth among the fields of the United States in barrels of crude produced; it ranks eighth since discovery.

Pennsylvania Exclusive of Bradford Field

Throughout the rest of Pennsylvania's oil-producing area sufficient cores have not been taken to permit zoning, as was done in Bradford field. Conclusions, therefore, had to be arrived at by a study of statistical data, well records, decline curves, past production records and all other information that could be supplied by men acquainted with the numerous districts.

An estimate was arrived at as follows: The figure 877,401,565 bbl. was accepted as the production of Pennsylvania from 1859 to Jan. 1, 1934. Of this, Bradford field produced 292,176,825 bbl., leaving 585,224,740 bbl. as representing oil produced in Pennsylvania outside of Bradford field. The productive oil acreage of Pennsylvania exclusive of Bradford field, as determined by planimeter measurement of an oil and gas fields map published by the State Survey in 1920, is 556,992 acres. Using this figure the recovery to date has been 1050 bbl. per acre. It was felt that the acreage figure used might be 15 per cent high but that the recovery might safely be assumed to have been 1050 bbl. per acre.

It was assumed that the pay sands in fields other than Bradford field would average 8 ft. in thickness, have a porosity of 13 per cent and show 60 per cent saturation. This would give an original oil content of 4845 bbl. per acre with 3795 bbl. per acre remaining in the reservoir. By reducing the acreage figure the suggested 15 per cent to 473,444, and using 3795 bbl. per acre, the figure 1,796,719,980 bbl. is obtained as representing barrels of oil in place.

It was further assumed that future recovery by secondary methods may equal 70 per cent of former recovery in this area, or 735 bbls. per acre. That is, that 347,981,340 (473,444 × 735) bbl. of recoverable oil remain to be produced in Pennsylvania outside of Bradford field.

Total Reserves in Pennsylvania

The above figures indicate a total reserve (oil in place) of 2,549,474,980 bbl., of which 652,133,340 bbl. is recoverable, and 1,897,341,640 bbl. is unrecoverable by present methods.

THE OIL AND GAS SANDS

With the exception of Bradford field little pertinent information on the sands of Pennsylvania is available. Intensive research, however, is well under way in the northern and north-central fields and some work has been done in the southern districts. As the life of the Pennsylvania industry may soon demand a lower production cost for crude, which probably means finding out what secondary methods of increasing recovery are adapted to the varying sand conditions, sand research promises to be an outstanding feature of Pennsylvania activities in the immediate future.

In Fig. 1 the succession of sands is shown and the productive range for each county is indicated graphically. It is recognized that the sands of the southern and northern fields may not lend themselves to single-column presentation. Much intensive study of subsurface geology remains to be done before reasonably accurate correlation can be made between the sands of the northern and southern areas. The chart

SYSTEM	GROUP OR FORMATION	GENERALIZED INTERVAL, FEET	STRATIGRAPHIC NAME	SUCCESSION OF SANDS IN SOUTHERN AND SOUTH-CENTRAL FIELDS
PENNSYLVANIAN	MONONGAHELA	0	PITTSBURGH COAL	
	CONEMAUGH		LOWER CONNELLSVILLE SANDSTONE	MURPHY STRAY
		180	MORGANTOWN SANDSTONE	MURPHY
		350	SALTSBURG SANDSTONE	LITTLE DUNKARD, 1ST COW RUN
		480	MAHONING SANDSTONE	BIG DUNKARD, HURRY UP
	ALLEGHENY	570	UPPER FREEPORT COAL	
		590	FREEPORT SANDSTONE	UPPER GAS, 2ND COW RUN
		670	KITTANNING SANDSTONE	MIDDLE GAS
		735	VANPORT LIMESTONE	
		760	CLARION SANDSTONE	LOWER GAS
	POTTSVILLE	830	HOMEWOOD SANDSTONE	FIRST SALT
		940	CONNOQUENESSING SANDSTONE	SECOND SALT
		1040	SHARON (OLEAN) CONGLOMERATE	THIRD SALT
MISSISSIPPIAN	MAUCH CHUNK	1100		MAXTON
		1160	GREENBRIER LIMESTONE	LITTLE LIME, SALVATION
				PENCIL CAVE (RED SHALE)
	POCONO	1180	LOYALHANNA LIMESTONE	BIG LIME, MOUNTAIN LIMESTONE, KENNER
		1220	BURGOON SANDSTONE	BIG INJUN, MOUNTAIN SAND
			PATTON RED SHALE	
				SQUAW
				PAPOOSE
		1775	BEREA SANDSTONE {CORRY SANDSTONE PITHOLE GRIT	BEREA, 3RD MOUNTAIN SAND
MIDDLE AND UPPER DEVONIAN	CATSKILL	1810		MURRYSVILLE, BUTLER-30-FOOT
		1875		HUNDRED-FOOT, GANTZ-50-FOOT
		1970		THIRTY-FOOT, NINEVEH 30-FOOT
		2045		SNEE
		2080		GORDON STRAY
		2200		GORDON
	CHEMUNG	2235		FOURTH
		2280		FIFTH, McDONALD
		2350		SIXTH, BAYARD
		2475		ELIZABETH
		3125		SPEECHLEY
		3360		BALLTOWN SANDS
		3800		BRADFORD GROUP
		4000		KANE GROUP
		4200		ELK SANDS
	PORTAGE TO ONONDAGA	6530	ONONDAGA (CORNIFEROUS LIMESTONE)	ONONDAGA LIME
L. DEV.	ORISKANY	6550	ORISKANY SANDSTONE	ORISKANY
L. SIL.	MEDINA	7800	MEDINA SANDSTONE	MEDINA (CLINTON OF OHIO)
ORD.	TRENTON	9300	TRENTON	

FIG. 1.—OIL AND GAS FIELDS OF PENNYSLVANIA.

therefore pretends to show only approximate relative position between the two sand columns. Fig. 1 differs from previously published charts chiefly in the equivalence shown for the northern region. The changes are based upon stratigraphic work in northwest Pennsylvania and southwest New York by K. C. Caster and upon subsurface work of C. R. Fettke in the Bradford and adjacent region. Needless to say, finality is not

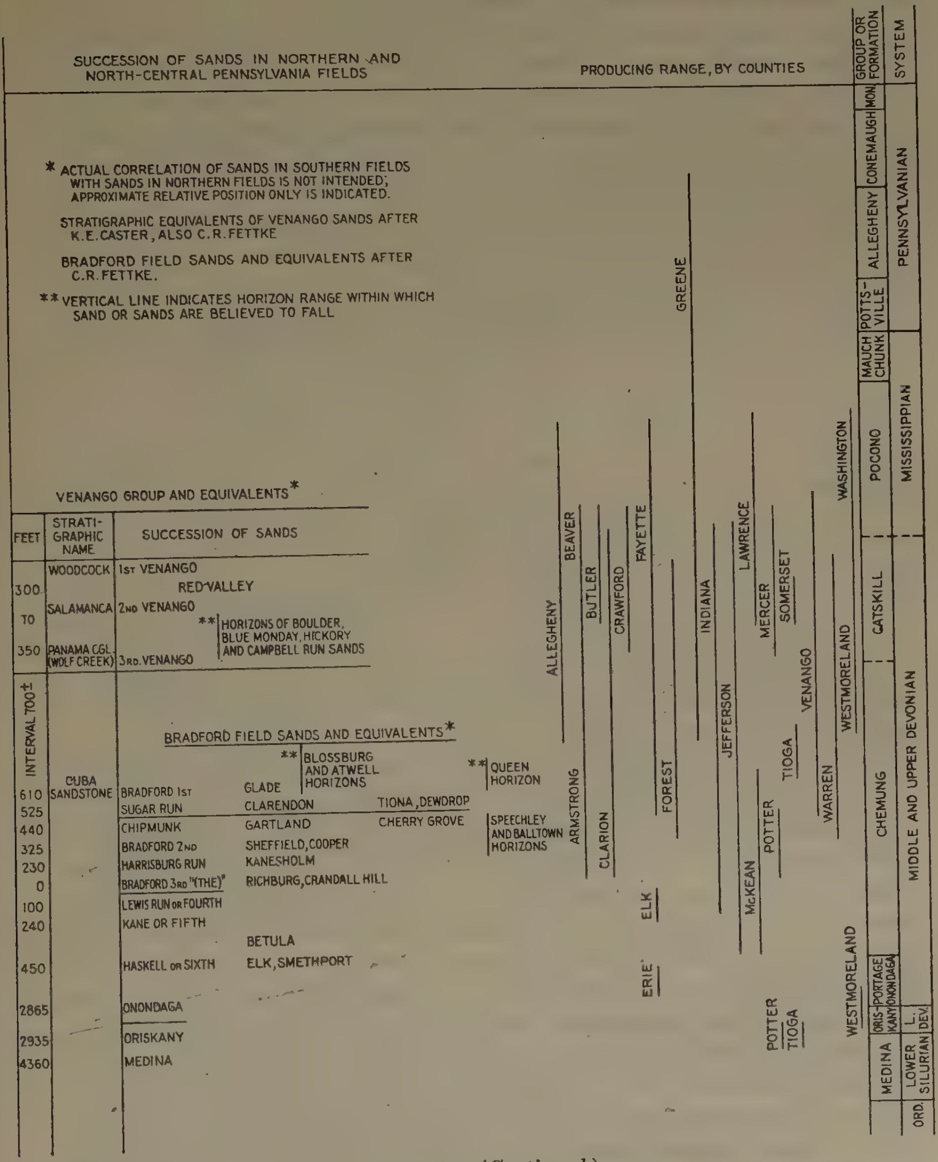

FIG. 1.—(*Continued.*)

implied in all instances. The productive oil and gas areas, and in a general way the areal distribution of sands, are shown in Fig. 2.

The following notes on the producing sands of certain counties represent statements submitted by contributors to Table 1, which are not adaptable to presentation in the table.

Beaver and Lawrence Counties.—The principal gas-producing sand is the Berea. Some gas has been produced locally from the Big Injun, Hundred-foot and Boulder sands. The principal oil-producing sands are the Berea in Lawrence County and the Berea and Hundred-foot in Beaver County.

Butler County.—Table 6 lists the producing sands, their depth, porosity and thickness.

TABLE 6.—*Producing Sands in Butler County*

Producing Sands	Average Depth, Ft.		Character	Porosity, Per Cent	Thickness, Ft.
	Top	Bottom			
Berea	1000	1100	ss	12	
Hundred-foot	1200	1400	ss	12	75–100
Third	1500	1600	ss	15	15– 20
Fourth	1550	1650	ss	15	15– 20
Snee	2000	2100	ss	12	15
Speechley	2300	2400	ss	12	25– 35

Erie County.—Gas is obtained in small amounts along the shore of Lake Erie from shale and included thin sandstones in the Portage and perhaps the Genesee formations.

Forest County.—Probably one-third of the oil produced in Forest County comes from the Balltown ("Second") sand, which lies about 1450 ft. below the top of the Corry (Berea) sandstone. The Balltown producing area is in the northeast part of the county and is defined roughly as the area between Kellettville, Henrys Mills and Watson Farm. The next most important sand is the Cooper, which lies about 258 ft. below the top of the Balltown, and is thought to be about the equivalent of the Second Bradford. It produces both oil and gas. The Cooper sand producing area is somewhat less than the Balltown area, extending between Minister, Henrys Mills and Watson Farm.

Near Marienville, in the southeast part of the county, gas and a little oil are produced from the Clarion, a sand of the Venango series, at 800 ft. In the western part of the county, from Tionesta north to the county line, oil production is from the 1st, 2d and 3d Venango sands. South of Tionesta and along the Clarion County line, oil is obtained from the Clarion and gas from the Speechley sand. Around Endeavor and Whig Hill the Queen sand (Glade of Warren County) yields gas.

Somerset County.—According to G. B. Richardson, most of the production of Texas School field comes from a sand near the middle of the Catskill. This field, a discovery of 1930, lies well east of the principal gas belt. Several wells had initial volumes of about a million cubic feet and further drilling in the region is reported to be planned for 1935.

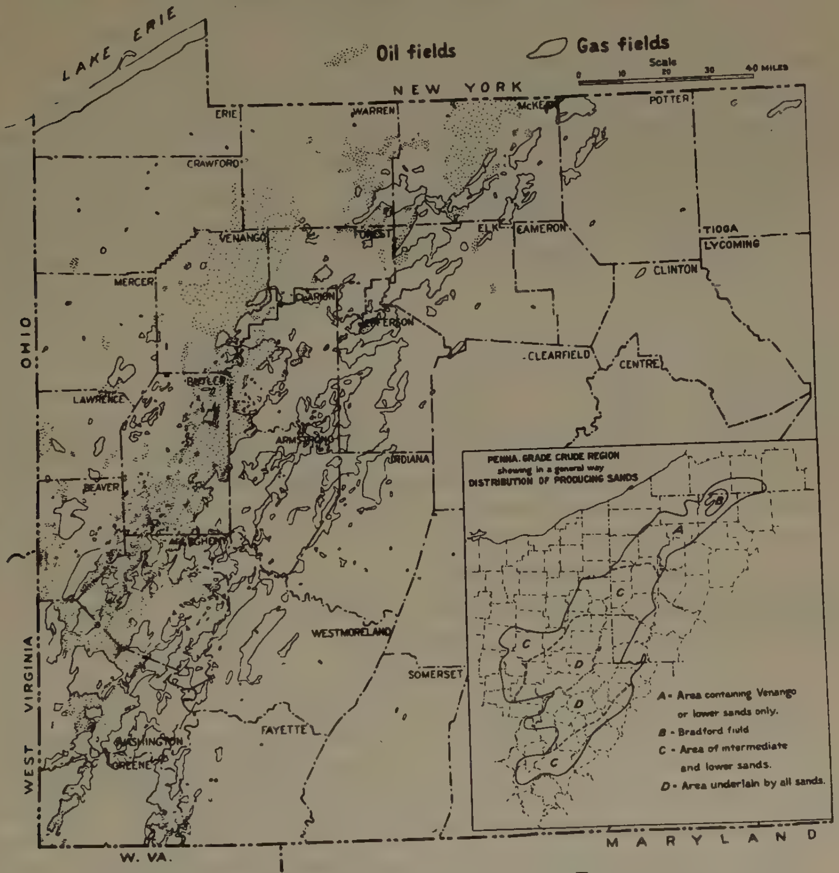

FIG. 2.—LOCATION OF OIL AND GAS FIELDS IN PENNSYLVANIA.

Venango County.—Producing sands are the Venango 1st, 2d, 3d and 4th, the Red Valley, Salt and Speechley. The reservoir rocks range from fine sandstone to coarse conglomerate; thickness varies between 10 and 40 ft. and porosity between 4 and 25 per cent.

Warren County.—Production is from the Venango 1st, 2d, 3d, 4th, Clarendon, Glade, Cooper and Balltown sands. The Venango 1st and 2d sands are 10 to 20 ft. thick, the Venango 3d averages about 30 ft., the Clarendon 18 ft., and the Cooper, Glade and Balltown 10 to 30 ft. In texture the reservoir rocks range from fine sandstone to conglomerate and vary in porosity between 4 and 25 per cent.

OIL AND GAS PRODUCTION STATISTICS

The oil and gas production table for Pennsylvania is notably incomplete. Pennsylvania's "fields" antedate the day of systematic development and record, and in consequence many of the desired data on early operations never were collected or now are hopelessly lost. Moreover, much of Pennsylvania's oil and gas acreage does not lend itself to discussion by fields. Most of the proven acreage occurs in large continuous areas; definitely circumscribed producing areas such as Bradford are exceptional. Since 1921 the Bureau of Statistics, Department of Internal Affairs, has reported annually the oil and gas production and the number of active oil and gas wells by counties. The number of wells connected to, and the number disconnected from, gathering systems is reported but no record is kept of new and abandoned wells as such in each county.

The only other agencies reporting Pennsylvania production and drilling use even larger units, such as southwest Pennsylvania, Kane to Butler, Butler-Armstrong, Venango-Clarion, etc., the only specific field mentioned being Bradford and in many instances Bradford, Pennsylvania, figures are not separated from Bradford, New York, figures. This method of reporting in large units or without consideration of field or political boundaries was common practice in the early days and has with few exceptions been constant practice. It is practically impossible to adapt many of the old figures, and many of the recent, too, for that matter, to even the compromise set-up that is used here in Table 1, a circumstance that will explain the many liberties taken in compiling that table.

ACKNOWLEDGMENTS

Information was contributed by the following persons and is acknowledged with thanks: Messrs. W. F. Clinger, Clinger Oil and Gas Co.; O. O. Cole and H. J. Little, South Penn Oil Co.; R. C. Conine, *Oil City Derrick;* J. J. Dunlevy, Valvolene Pipe Lines; C. R. Fettke, Carnegie Institute of Technology; E. H. Fortman, National Transit Co.; J. Gaddes, Allegheny Gas Co.; John T. Galey, Pittsburgh, Pa.; C. B. McClintock, The Sloan & Zook Companies; Norman E. Maxwell, Crew Levick Co.; J. J. Montgomery, Jr., United Natural Gas Co.; T. H. Myers, The Penn United Gas Co.; H. H. Phillips and C. A. Kemper, Phillips Gas & Oil Co.; E. O. Schillhahn, Manufacturers Light & Heat Co.; C. T. Sloan, Pennsylvania Gas Co.; H. W. Van Pelt, Pennsylvania Bureau of Statistics. The writer is indebted to Mr. George H. Ashley and Mr. R. W. Stone, of the Pennsylvania Geological Survey, for assistance in compiling and preparing the data. Much of the information on past production and drilling was taken from Bulletin M-19 of the Pennsylvania Geological Survey.

Petroleum in the Central Texas Area during 1934

By R. B. Kelly* and Paul R. Martin†

(New York Meeting, February, 1935)

The area comprising what is geographically termed "Central Texas" was somewhat less active in 1934 than in 1933. The year saw the completion of 182 dry holes and only 74 producing wells. Bexar, Williamson and Bastrop counties, with active fields such as Yturri-Southton, Byersville, North Dale and Cedar Creek contributed a majority of the new oil wells. Hilbig, in Bastrop County, 1933's most important discovery in the district, saw no development during the current year. New fields opened in 1934 were Byersville, a serpentine intrusion in Williamson County, and Manda, producing from similar material in Travis County. Like most of the other serpentine plugs, neither gives promise of covering a very large area. Other active counties were Bexar, Bastrop and Caldwell, although successful operations in each of them were limited to the old fields. The location of producing fields is shown on Fig. 1.

New Fields

Byersville.—Late in 1933, Fritz Fuchs completed Zeischang No. 1, eight miles south of Taylor, Williamson County, for an initial production of 25 bbl. per day. The oil is 37° Bé. A.P.I. gravity and is from Serpentine formation at approximately 900 ft. Additional drilling was carried on in 1934, and at the end of the year 18 producing wells had been completed, proving about 200 acres.

Manda.—The Manda field, or Kimbro field as it is termed by some, received its first production Sept. 10, 1934, when the Humble Oil & Refining Co. completed No. 1 C. J. Peterson as an 8-bbl. oil well. The new field is near Littig, in eastern Travis County, and is about 15 miles northeast of Austin. Production is found in serpentine formation between 650 and 750 ft. The same company's No. 1 Buck Christian, second well in the field, flowed 190 bbl. per day through a ⅞-in choke. Although only a small area has been definitely proven it is expected that present drilling will provide extensions in several directions.

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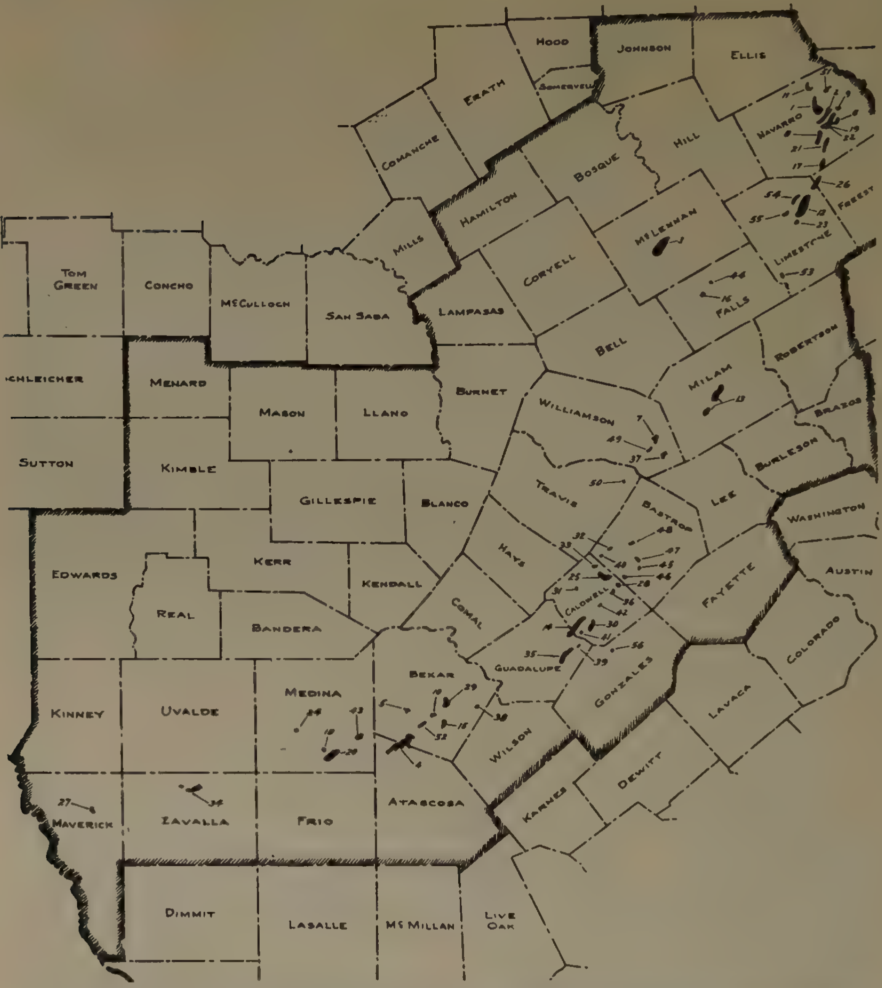

FIG. 1.—LOCATION OF PRODUCING OIL AND GAS FIELDS IN CENTRAL TEXAS AREA.

1. Corsicana.
2. Mildred (Elm Ridge).
3. South Bosque.
4. Somerset.
5. Gas Ridge.
6. Witherspoon-McKie.
7. Thrall.
8. Angus-Edens-Hodge.
9. Burke.
10. Alta Vista.
11. Rice-oil Ridge.
12. Mexia.
13. Minerva-Rockdale.
14. Luling.
15. Yturri-Southton.
16. Chilton.
17. Currie.
18. Ina.
19. Powell.
20. Adams.
21. Richland.
22. Woodbine area—shallow.
23. Bains Creek.
24. Taylor.
25. Lytton Springs.
26. Wortham.
27. Chittam.
28. Dale.
29. Eckert.
30. Salt Flat.
31. Larremore.
32. Yost.
33. Lytton Springs town site.
34. Cow Hill.
35. Darst Creek.
36. Buchanan.
37. Chapman.
38. Cooksey
39. Manford.
40. Schimmel-Batts.
41. Dunlap.
42. Branyon.
43. Chicon Lake.
44. Marlin.
45. Carroll.
46. North Dale.
47. Hilbig.
48. Cedar Creek.
49. Byersville.
50. Manda.

Depleted Fields

51. Chatfield.
52. Mission.
53. Kosse.
54. Nigger Creek.
55. Cedar Creek.
56. Ottine.

PEARSALL PROSPECT

In Frio County, 9 miles southwest of Pearsall, a gas well was completed by the Amerada Petroleum Corporation, showing an estimated two million cubic feet with a rock pressure of 1500 lb. The producing formation has been correlated as Edwards limestone. This was the second well drilled by the Amerada in the area and a third test is now shut down at 3908 ft. after plugging back from the Trinity sand at 10,050 ft. The lower formation was nonproductive and casing was ripped opposite the Navarro. At 3950 ft. the well produced oil, gas and salt water. It is probable that further drilling on this structure may result in opening a commercial field.

TRINITY SAND

Deeper drilling in 1934 resulted in completion of two important tests, in the fault line, neither of which found commercial production. The Trinity sand, long considered the possible source of additional oil at Mexia and Powell, was tested during the year. Wheelock & Collins, I. N. Cerf No. 1, in Navarro County, was abandoned at 6506 ft. without favorable showings, and Peyton Bros. Stubenrauch No. 1, in Limestone County, failed to secure more than a good gas show after drilling to 6116 ft. These tests, together with Amerada Petroleum Corporation's Halff and Oppenheimer No. 2, in Frio County, were the only Trinity sand tests during the year. Although all were failures, many operators are still confident that the horizon will become a major factor in Texas production in a few years.

OIL RECOVERY

Total production from the Central Texas area, birthplace of the oil industry in Texas, during the past 38 years has been 414,442,000 bbl. Oddly enough more than half of this amount has been produced within a radius of 35 miles of the "discovery field" at Corsicana. Approximately 242,000,000 bbl. has been recovered to date from sands of the Woodbine formation and about 15,000,000 bbl. from shallow sands in the Upper Cretaceous, principally the Nacatoch. During 1934 the Woodbine sand of the fault line fields produced 1,773,000 bbl. and the shallow fields in this area produced 85,000 barrels.

Second in importance from the standpoint of past yield are the Edwards limestone fields of Caldwell and Guadalupe counties. Total production to the end of 1934 has been approximately 126,000,000 bbl. The current year's yield from this horizon was slightly more than 7,000,000 bbl., taking first place for the year.

Serpentine intrusions in Bastrop, Williamson and surrounding counties have contributed some 17,000,000 bbl. of oil, of which approximately

TABLE 1.—*Oil and Gas Production in Central Texas*

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres			Total Oil Production, Bbl.
			Oil	Gas	Total	To End of 1934
1	Corsicana, *Navarro*	38	2,400	0	2,400	4,686,790
2	Mildred (Elm Ridge), *Navarro*	34	2,500	0	2,500	5,802,098
3	South Bosque, *McLennan*	32	5,300	0	5,300	80,970
4	Somerset, *Atascosa, Bexar*	22	11,390	0	11,390	9,470,885
5	Gas Ridge, *Bexar*	22	60	300	360	57,060
6	Witherspoon-McKie, *Navarro*	20	400	0	400	810,155
7	Thrall, *Williamson*	20	475	0	475	2,353,962
8	Angus-Edens-Hodge, *Navarro*	19	900	0	[illegible]	1,541,252
9	Burke, *Navarro*	19	250	0	250	310,380
10	Alta Vista[1], *Bexar*	19	300	0	300	100,660
11	Rice-Oil Ridge, *Navarro*	18	660	0	[illegible]	1,124,435
12	Mexia, *Limestone*	14	3,920	0	3,920	93,122,118
13	Minerva-Rockdale, *Milam*	13	4,000	0	4,000	3,098,327
14	Luling, *Caldwell, Guadalupe*	13	2,130	0	2,130	61,178,042
15	Yturri-Southton, *Bexar*	13	500	0	500	536,761
16	Chilton, *Falls*	12	40	0	40	90,360
17	Currie, *Navarro*	12	475	0	475	6,614,553
18	Ina, *Medina*	12	310	0	310	142,650
19	Powell, *Navarro*	11	2,600	0	2,600	109,849,321
20	Adams, *Medina*	10	0	2,000	2,000	0
21	Richland, *Navarro*	10	440	0	440	6,594,750
22	Woodbine Area—Shallow Field (Powell), *Navarro*	10	750	0	750	750,260
23	Bains Creek, *Limestone*	10	0	60	60	0
24	Taylor, *Medina*	10	30	0	30	25,664
25	Lytton Springs, *Caldwell*	9	1,360	0	1,360	7,782,319
26	Wortham, *Freestone, Limestone*	9	715	0	715	22,395,211
27	Chittam, *Maverick*	8	0	320	320	0
28	Dale, *Caldwell*	7	175	0	175	1,185,460
29	Eckert, *Bexar*	7	640	80	720	540,890
30	Salt Flat, *Caldwell*	7	1,195	0	1,195	32,103,286
31	Larremore, *Caldwell*	7	50	0	50	210,855
32	Yost, *Bastrop*	6	97	0	97	819,293
33	Lytton Springs Townsite, *Caldwell*	6	50	0	50	6,263
34	Cow Hill, *Zavalla*	6	0	1,000	1,000	0
35	Darst Creek, *Guadalupe*	6	1,670	0	1,670	32,080,485
36	Buchanan, *Caldwell*	6	75	0	75	155,458
37	Chapman, *Williamson*	5	350	0	350	3,707,385
38	Cooksey, *Bexar*	5	50	0	50	59,405
39	Manford, *Guadalupe*	5	20	0	20	346,726
40	Schimmel-Batts, *Bastrop*	4	50	0	50	3,600
41	Dunlap, *Caldwell*	4	25	0	25	224,215
42	Branyon, *Caldwell*	4	20	0	20	73,913
43	Chicon Lake, *Medina*	4	350	225	575	10,800
44	Marlin-Satin, *Falls*	3	10	0	10	11,200
45	Carroll, *Bastrop*	2	40	0	40	10,150
46	North Dale, *Bastrop*	2	250	0	250	270,875
47	Hilbig, *Bastrop*	2	250	0	250	510,585
48	Cedar Creek, *Bastrop*	2	160	0	160	150,500
49	Byersville, *Williamson*	1	200	0	200	36,500
50	Manda, *Travis*	0.25	20	0	20	440
	Depleted Fields, Arranged Chronologically as to Discovery Date					
		Life				
51	Chatfield[2], *Navarro*	5	0	150	150	0
52	Mission[3], *Bexar*	16	200	0	200	63,000
53	Kosse[4], *Limestone*	8 days	10	0	10	33,000
54	Nigger Creek[5], *Limestone*	5	170	0	170	2,998,810
55	Cedar Creek[6], *Limestone*	4	30	0	30	297,945
56	Ottine[7], *Gonzales*	0.5	10	0	10	12,000
57	Total		48,072	4,135	52,207	414,442,022

[1] Austin Chalk producing horizon depleted.
[2] Discovered 1905; depleted 1910.
[3] Discovered 1912; depleted 1928.
[4] Discovered 1922; depleted 1922.
[5] Discovered 1926; depleted 1931.
[6] Discovered 1927; depleted 1931.
[7] Discovered 1929; depleted 1929.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.			Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells		
												During 1934	
	During 1933	During 1934	Daily Average during Nov., 1934	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned
1	34,675	24,090	66	1,953	130	0.25	0	0	0	0	1,280	0	9
2	47,180	23,725	65	2,321	145	0.25	0	0	0	0	1,270	0	54
3	8,550	6,570	18	15	5	0.36	0	0	0	0	123	0	38
4	306,075	260,775	715	832	28	0.92	0	0	0	0	1,046	1	124
5	4,745	4,220	10	951	63	0.77	8,170	202	170	0.7	120	0	9
6	8,030	3,960	11	2,025	156	0.26	0	0	0	0	85	0	0
7	16,790	19,800	55	4,956	x	4.23	0	0	0	0	15	2	0
8	13,505	7,200	20	1,713	95	0.48	0	0	0	0	205	0	16
9	4,645	2,920	8	1,242	113	0.62	0	0	0	0	85	0	6
10	3,285	2,160	6	336	15	0.33	0	0	0	0	41	6	6
11	10,585	8,760	24	1,704	142	0.38	0	0	0	0	95	0	4
12	840,600	781,518	2,311	23,756	475	8.11	0	0	0	0	550	0	4
13	93,075	80,688	212	775	52	0.54	0	0	0	0	575	0	88
14	2,343,300	2,086,495	6,500	28,722	287	13.4	0	0	0	0	544	0	26
15	28,800	27,915	78	1,074	107	0.82	0	0	0	0	135	20	3
16	5,475	2,160	4	2,259	452	4.0	0	0	0	0	3	0	1
17	58,500	56,053	159	13,925	696	9.94	0	0	0	0	54	0	0
18	5,840	2,300	8	460	31	0.62	0	0	0	0	31	1	0
19	964,830	884,491	2,311	42,250	939	14.01	0	0	0	0	821	0	26
20	0	0	0	0	0	0	11,121	386	360	1.5	46	1	2
21	11,680	13,150	37	14,988	749	12.33	0	0	0	0	107	0	0
22	32,120	13,680	38	1,000	67	1.0	0	0	0	0	185[11]	0	32
23	0	0	0	0	0	0	x	40	38.4	0.1	5	0	1
24	2,920	2,190	6	855	57	3.0	0	0	0	0	6	0	0
25	192,720	161,072	450	5,722	x	2.53	0	0	0	0	295	0	24
26	41,400	39,066	124	31,322	895	8.86	0	0	0	0	322	0	0
27	0	0	0	0	0	0	3,854.8	844.5	792.1	3.5	5	0	0
28	266,450	90,795	255	6,774	x	7.08	0	0	0	0	39	1	0
29	178,850	148,349	412	845	85	3.75	2,995	390	350	1	130	6	2
30	1,861,500	1,639,098	4,500	26,865	895	19.65	0	0	0	0	353	0	17
31	23,725	14,890	43	4,217	121	8.6	0	0	0	0	12	0	1
32	39,420	29,795	83	8,446	x	10.38	0	0	0	0	12	0	4
33	400	183	0.5	125	x	0.5	0	0	0	0	3	0	0
34	0	0	0	0	0	0	528.5	99	131.4	1.4	7	0	0
35	3,212,000	3,321,976	9,100	19,210	640	35.14	0	0	0	0	261	0	2
36	20,805	16,875	45	2,073	x	9.0	0	0	0	0	6	0	0
37	255,597	178,850	490	10,593	x	5.7	0	0	0	0	110	0	5
38	16,425	9,000	25	1,188	119	1.78	0	0	0	0	15	0	1
39	19,710	17,898	45	17,336	578	15.0	0	0	0	0	4	0	0
40	1,800	600[8]	0	72	x	0	0	0	0	0	3	0	0
41	20,075	10,950	20	8,968	897	4.0	0	0	0	0	6	1	0
42	13,140	10,685	28	3,696	x	14.0	0	0	0	0	2	0	0
43	1,800	7,300	20	31	x	0.91	598.7	273.7	61.2	0.4	25	0	1[1]
44	4,400	1,200	0[9]	1,120	56	0[9]	0	0	0	0	2	0	1
45	1,400	8,750	64	254	x	32.0	0	0	0	0	2	1	0
46	77,286	193,589	555	1,084	x	32.65	0	0	0	0	17	5	0
47	228,305	282,280	624	2,042	x	52.0	0	0	0	0	12	0	0
48	15,000	135,000	200	941	x	14.29	0	0	0	0	14	8	0
49	0	36,500	328	183	x	18.22	0	0	0	0	18	18	0
50	0	440	x[10]	22	x	x[10]	0	0	0	0	3	3	1
	Depleted Fields, Arranged Chronologically as to Discovery Date												
51	0	0	0	0	0	0	4,750	0	0	0	15	0	0
52	0	0	0	315	13	0	0	0	0	0	32	0	0
53	0	0	0	3,300	x	0	0	0	0	0	1	0	0
54	0	0	0	17,640	1,176	0	0	0	0	0	75	0	0
55	0	0	0	9,932	993	0	0	0	0	0	14	0	0
56	0	0	0	1,200	80	0	0	0	0	0	1	0	0
57	11,337,413	10,669,961	30,073				32,018	2,235.2	1,903.1	8.6	9,243	74	508

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[b] Footnotes to column headings and explanation of symbols are on page 249.

[8] Produced 5 barrels per day first 4 months, then shut in.

[9] 1 well produced first 4 months of 1934 only.

[10] No outlet and limited storage, estimated 120 barrels daily.

[11] Includes 55 Woodbine depleted wells plugged back and casing ripped to produce shallow oil.

[12] 1 gas well abandoned during 1934.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells				Average Depth, Ft.		Oil Production Methods at End of 1934				Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1934				
	At End of 1934						Number of Wells					Average at End of		Gravity A.P.I. at 60° F.				
	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas Lift	Injection into Reservoir[d]	Initial	1933	1934	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	6	260	0	266	1,260	800	0	260	0	0	x	x	x	37.1	35.9	36.6	0.3	P
2	8	252	0	260	1,250	740	0	252	0	0	x	x	x	[16]	[16]	[16]	0.6	P
3	13	37	0	50	475	450	0	37	0	0	x	x	x	42	40	41	0.2	P
4	60	715	0	775	2,100	1,400	0	715	0	0	x	x	x	39.4	34	36.4	1.4	P
5	0	13	57	70	[13]	[13]	0	13	0	0	220	140	135	23	21	22	0.4	P
6	2	40	0	42	875	825	0	40	0	0	x	x	x	20	18	19	0.6	P
7	0	13	0	13	1,000	700	0	13	0	0	x	x	x	37.6	36.4	37	0.3	P
8	2	40	0	42	1,185	740	0	40	0	0	x	x	x	36.5	35	36	0.6	P
9	0	13	0	13	480	400	0	13	0	0	x	x	x	21	21	21	0.8	P
10	6	12	0	18	250	220	0	12	0	0	x	x	x	36	34	35	0.3	P
11	9	55	0	64	1,000	960	0	55	0	0	x	x	x	36.4	35.2	35.7	0.4	P
12	15	270	0	285	3,085	3,000	0	270	0	0	x	x	x	36	34.2	35	0.3	P
13	16	380	0	396	1,700	600	0	380	0	0	x	x	x	40	36.4	38	0.2	P
14	10	475	0	485	2,200	2,100	0	475	0	0	x	x	x	28	26	27	0.9	A
15	17	78	0	95	800	600	0	78	0	0	x	x	x	32.5	31.4	32	0.5	P
16	0	1	0	1	1,160	1,080	0	1	0	0	x	x	x	32	31.6	32	0.8	P
17	0	16	0	16	2,990	2,930	0	16	0	0	x	x	x	41	40	40.2	0.2	P
18	2	11	0	13	960	940	0	11	0	0	x	x	x	19	19	19	0.7	A
19	15	150	0	165	3,000	2,925	0	150	0	0	x	x	x	38	36.8	37.2	0.3	P
20	6	0	15	21	1,000	900	0	0	0	0	400	175	120					
21	0	3	0	3	3,040	2,975	0	3	0	0	x	x	x	38.4	38.4	38.4	0.3	P
22	6	32	0	38	1,650	1,450	0	32	0	0	x	x	x	34.8	34.1	34.5	0.4	P
23	0	0	2	2	2,960	2,945	0	0	0	0	875	355	210					
24	0	2	0	2	400	290	0	2	0	0	x	x	x	18	18	18	0.4	P
25	30	148	0	178	1,900	1,600	0	148	0	0	x	x	x	38.6	37.8	38.1	0.4	P
26	0	14	0	14	3,050	2,990	0	14	0	0	x	x	x	38.6	36.2	37.3	0.2	P
27	0	0	3	3	5,590	5,525	0	0	0	0	2,200	1,350	1,240					
28	8	28	0	36	2,250	1,915	0	28	0	0	x	x	x	38.4	36	37	0.2	P
29	26	84	5	115	[14]	[14]	0	84	0	0	200	160	148	35	33	34	0.3	P
30	18	211	0	229	2,740	2,670	0	211	0	0	x	x	x	36	36	36	0.6	P
31	0	5	0	5	1,315	1,285	0	5	0	0	x	x	x	23.4	23	23	0.2	P
32	0	8	0	8	1,500	1,335	0	8	0	0	x	x	x	28	26	27	0.3	P
33	0	1	0	1	1,820	1,535	0	1	0	0	x	x	x	31.5	31.5	31.5	0.4	P
34	0	0	7	7	800	675	0	0	0	0	295	260	225					
35	11	248	0	259	2,700	2,650	6	242	0	0	x	x	x	37	35	36	0.8	P
36	0	5	0	5	2,075	1,750	0	5	0	0	x	x	x	37	35	36	0.2	P
37	11	75	0	86	1,915	1,730	0	75	0	0	200	110	100	36.7	35.2	36	0.2	P
38	0	14	0	14	1,460	1,440	0	14	0	0	x	x	x	34	32	33	0.4	P
39	0	3	0	3	2,320	2,260	0	3	0	0	x	x	x	37.3	36.7	37.3	0.9	P
40	3	0	0	3	1,900	1,400	0	0	0	0	x	x	x	34.8	33.8	34.4	0.2	P
41	0	5	0	5	2,300	2,290	0	5	0	0	x	x	x	37	35	36	0.6	P
42	0	2	0	2	2,000	1,900	0	2	0	0	x	x	x	38	36	37	0.8	P
43	0	22	4	26	[15]	[15]	0	9	3	G2	420	240	210	[17]	[17]	[17]	0.1	P
44	1	0	0	1	1,160	1,000	0	0	0	0	x	x	x	34.5	33.9	34.2	0.4	P
45	0	2	0	2	2,378	2,300	0	2	0	0	x	x	x	36	36	36	0.2	P
46	0	17	0	17	2,160	2,025	0	17	0	0	x	x	x	38	36	37	0.3	P
47	0	12	0	12	2,575	2,450	12	0	0	G1	1,240	1,150	1,086	37.2	37.2	37.2	0.2	P
48	0	14	0	14	1,700	1,650	0	14	0	0	x	x	x	34	34	34	0.2	P
49	0	18	0	18	900	850	0	18	0	0	x	x	x	37	37	37	0.2	P
50	2	0	0	2	757	720	1	1	0	0	x	x	x	34	34	34	0.4	P
Depleted Fields, Arrainged Chronologically as to Discovery Date																		
51	0	0	0	0	1,020	880	0	0	0	0	250	0	0					
52	0	0	0	0	420	395	0	0	0	0	x	0	0	28	26	27	0.3	P
53	0	0	0	0	3,767	x	0	0	0	0	x	0	0	32	32	32	0.3	P
54	0	0	0	0	2,870	2,820	0	0	0	0	x	0	0	40	40	40	0.3	P
55	0	0	0	0	2,940	2,885	0	0	0	0	x	0	0	37	37	37	0.3	P
56	0	0	0	0	3,780	3,765	0	0	0	0	x	0	0	32	32	32	0.2	P
57	303	3,804	93	4,200			19	3,774	13	G3								

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[13] Gas, bottom 830, top 780; oil, bottom 280, top 230.

[14] Gas, bottom 670, top 655; oil, bottom 790, top 620.

[15] Gas, bottom 495, top 480; oil, shallow, bottom 320 top 240; oil, deep, bottom 810, top 760.

[16] Both light and heavy oil, same horizon, each of paraffin base; heavy, maximum 20, minimum 18, weighted average 19; light, maximum 25, minimum 21, weighted average 23.

[17] Shallow, maximum 22, minimum 20, weighted average 21; deep, maximum 36, minimum 34, weighted average 35.

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1934		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested	
	B.t.u. per Cu. Ft.	Gal. Gasoline per Cu. M. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
1	1,040	1.8	Nacatoch, Corsicana	CreU	Ss	13–19	15	AF, AM	118	Woodbine sand	3,408
2	1,040	1.7	[18]	CreU	Ss	14–20	16	AF, AM	300	Woodbine sand	3,570
3	1,225	2.0	Basal Walnut	CreL	DL	22	3	AF	100	Basal Trinity	1,800
4	*x*	*x*	Taylor, Navarro	CreU	SH	22	30	F	75	Trinity sand	5,311
5	1,120	0.5	Taylor sand	CreU	[19]	15–20	15	A	39	Glenrose Ls	2,250
6	1,040	1.6	Nacatoch sand	CreU	Ss	14–19	13	Af	25	Woodbine sand	3,480
7	*x*	0.8	Serpentine	CreU	P	20–30	*x*	[25]	23	Trinity sand	3,290
8	1,040	2.8	Nacatoch, Corsicana	CreU	Ss	12–18	18	AF, AM	65	Woodbine sand	3,335
9	1,040	*x*	Nacatoch sand	CreU	Ss	18	11	A	25	Woodbine sand	3,356
10	1,135	*x*	Navarro sand	CreU	S	15–20	23	F	28	Trinity sand	4,535
11	1,040	1.9	Nacatoch sand	CreU	Ss	12–17	12	AF, AM	28	Woodbine sand	3,086
12	1,152	2.5	Woodbine sand	CreU	SH	25	50	F	143	Trinity sand	6,116
13	*x*	2.5	Upper Navarro	CreU	S	16	15	F	42	Edwards Ls	5,000
14	955	1.5	Edwards Ls	CreL	L	5–30	100	F	76	Schist	7,859
15	*x*	1.8	Navarro sand	CreU	S	16	10	F	32	Glenrose Ls	3,850
16	*x*	2.1	Georgetown Ls	CreL	LS	23	5	AF	23	Glenrose Ls	2,025
17	1,040	2.5	Woodbine sand	CreU	SH	22	20	F	51	Woodbine sand	3,300
18	*x*	*x*	Escondido sand	CreU	SH	*x*	15	F	33	Edwards Ls	2,048
19	1,080	2.5	Woodbine sand	CreU	SH	25	45	F	68	Trinity sand	6,506
20	999	2.3	Escondido sand	CreU	S	*x*	20	F	12	Edwards Ls	2,289
21	1,060	2.5	Woodbine sand	CreU	SH	25	20	F	23	Glenrose Ls	5,415
22	*x*	*x*	Taylor, Navarro	CreU	Ss	14–20	15	F	49	Trinity sand	6,506
23	1,040	0.4	Woodbine sand	CreU	SH	20	15	F	9	Woodbine sand	3,208
24	*x*	1.4	Taylor sand	CreU	SH	15	15	[23]	15	Edwards Ls	1,285
25	1,040	1.5	Serpentine	CreU	P	14	*x*	[25]	44	Edwards Ls	2,292
26	1,080	2.5	Woodbine sand	CreU	SH	25	35	F	62	Glenrose Ls	4,825
27	1,020	4.6	Glenrose Ls	CreL	L	*x*	50	A	8	Basal Trinity sands	7,635
28	*x*	1.5	Serpentine	CreU	P	15	*x*	[25]	7	Edwards Ls	2,661
29	1,140	1.8	Navarro	CreU	S	16	10	F	12	Edwards Ls	1,590
30	*x*	2.5	Edwards Ls	CreL	L	30	30	F	36	Edwards Ls	2,918
31	1,120	1.3	Edwards Ls	CreL	L	*x*	35	F	6	Glenrose Ls	2,150
32	*x*	1.4	Serpentine	CreU	P	15–25	*x*	[25]	8	Austin chalk	2,066
33	*x*	*x*	Serpentine	CreU	P	12	*x*	[25]	12	Edwards Ls	2,050
34	1,015	0.2	Escondido sand	CreU	SH	*x*	20	A	10	Glenrose Ls	4,709
35	*x*	2.3	[20]	CreL	L	26	30	F	20	Edwards Ls	3,200
36	*x*	1.6	Serpentine	CreU	P	12	*x*	[25]	3	Edwards Ls	2,483
37	1,025	0.8	Serpentine	CreU	P	20	*x*	[25]	46	Edwards Ls	3,236
38	*x*	0.3	Taylor sand	CreU	S	13	10	F	7	Edwards Ls	2,250
39	*x*	1.5	Edwards Ls	CreL	L	35	30	F	4	Edwards Ls	2,800
40	1,120	1.5	Serpentine	CreU	P	13	*x*	[25]	8	Austin chalk	2,001
41	*x*	1.5	Austin chalk	CreU	C	*x*	10	F	9	Edwards Ls	2,420
42	*x*	1.5	Crevice, Top Austin	CreU	C	*x*	*x*	F	8	Edwards Ls	2,450
43	1,095	0.5	[21]	CreU	[22]	13	*x*	[24]	13	Edwards Ls	1,725
44	*x*	*x*	Buda, Georgetown	CreL	L	20	20	AF	8	Glenrose Ls	1,409
45	1,025	2.5	Serpentine	CreU	P	12	*x*	[25]	2	Edwards Ls	2,919
46	*x*	1.5	Serpentine	CreU	P	15	*x*	[25]	14	Edwards Ls	2,950
47	1,300	1.0	Serpentine	CreU	P	12	*x*	[25]	5	Serpentine	2,715
48	1,010	0.5	Serpentine	CreU	P	15–25	*x*	[25]	8	Edwards Ls	2,300
49	1,010	2.0	Serpentine	CreU	P	15–25	*x*	[25]	15	Austin chalk	1,500
50	*x*	0.4	Serpentine	CreU	P	15–25	*x*	[25]	2	Taylor marls	850
Depleted Fields, Arranged Chronologically as to Discovery Date											
51	1,110	1.8	Taylor sand	CreU	Ss	*x*	13	A	7	Woodbine sand	3,057
52	1,120	1.3	Navarro sand, shale	CreU	SH	18	25	F	15	Glenrose Ls	3,550
53	*x*	*x*	Unknown	*x*	*x*	*x*	*x*	Crev.	22	Glenrose Ls	6,050
54	*x*	*x*	Woodbine sand	CreU	SH	25	15	F	35	Woodbine sand	3,509
55	*x*	*x*	Woodbine sand	CreU	SH	25	10	F	9	Woodbine sand	3,310
56	*x*	*x*	Taylor sand	CreU	S	*x*	15	F	3	Edwards Ls	4,281

[18] Nacatoch, Corsicana, Taylor, and Navarro.
[19] Gas, S; oil, SH.
[20] Taylor Marl, Austin Chalk cavities, and Edwards limestone.
[21] Shallow, Taylor and Navarro; deep, Serpentine.
[22] Shallow, S; deep, P.
[23] Crev., F.
[24] Shallow, D; deep, Intrusion.
[25] Intrusion.

TABLE 2.—*Summary of Drilling Operations in Central Texas*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to January 1, 1935											Completed during 1934									Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes										Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes								Productive Wells (For Details, See Table 1)		
	Total Depths, Ft.											Total Depths, Ft.										
	400–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000	8000–9000	Total		400–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	Total		Within Fields	Exploratory
Atascosa	8	19	16	5	6	0	0	0	0	54	501	0	0	2	0	1	0	0	3	1	0	0
Bandera	1	0	0	1	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1
Bastrop	11	85	124	25	3	1	0	1	0	250	60	0	9	17	0	0	0	0	26	14	2	2
Bell	5	9	1	2	1	0	0	0	0	18	0	0	0	0	0	1	0	0	1	0	0	0
Bexar	205	134	100	43	8	2	0	0	0	492	998	10	16	0	0	0	0	0	26	32	1	1
Blanco	7	3	0	0	0	0	0	0	0	10	0	0	1	0	0	0	0	0	1	0	0	0
Bosque	16	8	2	2	0	0	0	0	0	28	2[1]	2	1	0	0	0	0	0	3	0	0	1
Brazos	2	1	5	4	1	0	0	0	0	13	0	2	0	1	0	0	0	0	3	0	0	1
Burleson	4	10	7	4	0	0	1	0	0	26	0	0	1	2	0	0	0	1	4	0	0	0
Burnet	3	0	1	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	1
Caldwell	28	51	148	44	5	2	1	1	0	280	1260	0	3	12	1	0	0	0	16	2	2	3
Comal	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Coryell	0	4	1	3	1	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	1
Edwards	3	3	3	4	0	0	0	0	1	14	0	0	0	0	0	0	0	0	0	0	0	1
Ellis	5	7	5	4	0	0	0	0	0	21	0	0	1	0	0	0	0	0	1	0	0	1
Falls	24	66	17	14	1	0	0	0	0	122	5	0	2	1	0	0	0	0	3	0	0	1
Fayette	1	0	9	5	2	0	0	0	0	17	0	0	0	0	2	0	0	0	2	0	0	0
Freestone	12	31	170	115	14	4	0	0	0	346	247	0	0	0	0	4	2	0	6	0	0	3
Frio	0	3	5	5	0	0	2	0	0	15	0	0	1	1	0	0	0	1	3	0	0	1
Gillespie	2	2	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	1
Gonzales	10	17	18	10	12	3	0	0	0	70	1	0	0	0	1	0	0	0	1	0	0	0
Guadalupe	27	59	191	19	0	0	0	0	0	296	290	1	1	6	1	0	0	0	9	0	1	2
Hamilton	0	0	1	14	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	1
Hays	9	2	6	1	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0
Hill	33	18	6	3	1	0	0	0	0	61	2[1]	0	0	0	0	0	0	0	0	0	0	1
Johnson	2	3	0	2	1	0	0	0	0	8	0	1	0	0	0	0	0	0	1	0	0	0
Kendall	4	6	5	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0
Kerr	0	3	4	2	5	1	0	0	0	15	0	0	0	1	0	1	0	0	2	0	0	2
Kimble	6	4	3	3	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0
Kinney	2	2	3	4	1	1	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0
Lampasas	6	7	5	1	1	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	1
Lee	3	8	3	2	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	1
Limestone	34	42	196	150	8	3	2	0	0	435	720	1	2	2	3	2	0	1	11	0	0	8
Llano	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
McLennan	131	95	64	16	4	1	0	0	0	311	123	1	0	0	0	0	0	0	1	0	0	0
Mason	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Maverick	11	3	2	3	3	7	1	1	0	31	5	2	1	0	0	0	0	0	3	0	0	2
Medina	40	64	27	10	2	0	0	0	0	143	108	0	1	1	0	0	0	0	2	2	0	1
Menard	10	7	2	9	0	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0	1
Milam	10	70	39	20	4	0	0	0	0	143	575	0	0	3	0	0	0	0	3	0	0	2
Navarro	332	268	187	77	6	2	1	0	0	873	4191	2	2	0	3	1	0	1	9	0	0	4
Real	1	2	0	2	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	1
Robertson	3	3	2	8	2	1	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	1
Travis	22	29	5	2	0	0	0	0	0	58	3	7	3	0	0	0	0	0	10	3	0	2
Uvalde	6	10	7	4	2	1	0	0	0	30	0	2	0	1	0	0	1	0	4	0	0	1
Williamson	20	57	71	5	0	0	0	0	0	153	143	5	17	2	0	0	0	0	24	20	4	3
Wilson[1]	5	13	13	9	4	2	0	0	0	46	2[1]	2	1	0	0	0	1	0	4	0	0	1
Zavalla	3	29	5	5	1	0	1	0	0	44	7	0	0	0	0	0	0	0	0	0	0	1
Total	1069	1258	1479	661	100	31	9	3	1	4611	9243	38	63	52	11	10	4	4	182	74	10	55

[1] No production now, so small and short-lived, not recorded as field.

1,000,000 bbl. was produced during 1934. All of the recent discoveries of importance in the district have been from serpentine plugs, and active exploration for additional areas was under way at the close of the year.

Average daily production from the 3806 oil wells in the Central Texas area was 7.9 bbl. during November, 1934. It is interesting to note that the average recovery to Jan. 1, 1935, of all producing wells drilled has been approximately 45,000 bbl. per well and the average for both productive and nonproductive wells has been 30,000 barrels.

PRORATION OF OIL

The year 1934 saw even less necessity for proration in Central Texas than existed in 1933. Hilbig and Darst Creek were restricted to some extent, but Salt Flat was producing within one or two per cent of its maximum capacity. "Marginal well" allowables were sufficiently high in the remaining fields to avoid the necessity of prorating.

PRODUCTION

Improvement in the price of crude oil made possible the reconditioning of many wells that had been neglected during the previous three years. Wells that had been shut down because of unprofitable operation were again pumped, giving employment to many idle men. Acid treatment of lime formations proved highly successful in some areas, particularly Luling, although serpentine fields did not respond. As a result of these practices and increases in allowables, production from many of the older fields showed a marked improvement. It is anticipated that more of the 300 idle oil wells will be worked over during 1935 and again operated at a profit.

No new casinghead gasoline plants were constructed during the year.

Drilling in the Central Texas area should increase during 1935, and most of this activity will be of a wildcat nature. Search for serpentine plugs probably will take first importance, with exploration for producing fields in the Edwards limestone a close second. Development of the Woodbine sand will be carried on in Freestone, Limestone and adjoining counties.

Development and Production in the East Texas District

By A. R. Denison,* Member A.I.M.E.

(New York Meeting, February, 1935)

The area discussed in this report comprises a group of 38 counties lying in the northeast corner of Texas. It covers all, and extends beyond, the borders of what is commonly described as the East Texas Basin. It includes two major oil fields, Van and East Texas; two major gas fields, Bethany and Waskom; and a number of fields, both oil and gas, of lesser importance. All commercial oil production comes from beds of Upper Cretaceous age and almost exclusively from the basal member, the Woodbine sand. Gas is produced from both Upper and Lower Cretaceous beds with the newer production from the older beds.

East Texas Field

This field continued as in 1932 and 1933 to dominate the drilling and production situation throughout the oil business. A total of 3681 producing wells was completed in this field during 1934. This is an increase of 1215 over the 2466 producers completed during 1933. Total wells

Table 1.—*Oil and Gas Production in the East Texas District*

Line Number	Field[1], *County*	Age, Years to End of 1934	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934
1	Caddo, *Marion*	30	980			980	7,497,843	42,602	34,813	82.5
2	Bethany, *Panola*	16			21,000	21,000				
3	Waskom, *Harrison*	10			7,500	7,500				
4	Boggy Creek, *Anderson-Cherokee*	7¾		200		200	4,103,940	290,295	218,018	590
5	Van, *Van Zandt*	5½	4,385			4,385	72,801,204	17,225,296	14,674,766	34,200
6	East Texas, *Rusk, Gregg, Upshur, Smith, Cherokee*	4⅓	116,000		4,000	120,000	644,278,235*x*	211,586,118*x*	176,829,941*x*	454,127*x*
7	Long Lake, *Anderson*	1⅙		100*x*	10,000*x*	10,100*x*	47,107	6,079	41,028	137
8	Cayuga, *Anderson*	⅚		2,500*x*	2,300*x*	4,800*x*	541,138		541,138	3,068
9	Shell, *Leon*	1			6,000*x*	6,000*x*				
10	Kittrell, *Houston*	⅓	100			100	40,392		40,392	259

[a] Footnotes for column heads and explanation of symbols are on page 249.

[1] The Nacogdoches, Shelbyville and DeBerry fields dropped from the report because the first two are long since exhausted and the third was inactive during the year with no wells completed and no production.

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completed as producers at the end of 1934 were 15,556. The producers completed in the East Texas field constitute 29 per cent of all such wells completed in the United States during 1934. This compares with 28 per cent for the year 1933 for the same statistics. The legally allowed production for the year 1934 is 156,928,833 bbl., while the total oil estimated to be produced, including so-called "hot" oil, is 176,129,941. This is a marked decrease from 1933 when 211,586,118 bbl. was estimated to have been produced legally and otherwise. The daily allowable for the field fluctuated from a low of 392,564 in January to a peak of 505,802 during June, while the average for the year was 429,942. The estimated excess production varied from a minimum of 20,000 during December to a maximum of 113,000 during October, with the average for the year estimated to be in excess of 54,000 bbl. daily. The price of oil in this field remained constant during the year at $1 per barrel.

Producing limits of the field were enlarged during the year to take in approximately 4000 additional acres. This was in part due to an extension of the eastern and western edges of the field. By use of more careful drilling methods on the east side, wells were completed in very thin sands, while by very thin penetration of the sand on the west side, oil wells were completed above the water level. In addition a slight extension was made at the north end of the field beyond limits which formerly were considered to mark the edge of production. More than 3500 wells have

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1934		At End of 1934				
	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	7,651	510	2.5					78		1		33			33
2				97,473	7,930	6,828	23	338	5	10				156	156
3				40,776	1,736	1,756	5	208		2				81	81
4	20,520	603.5	28.1	6,756	402	269	0.9	39			1		20		21
5	16,602	62[2]	76					450	53		15[6]	435			450
6	5,549x	198x	30.1x	[4]				15,556	3,681	25x	x	15,515		16	15,531
7	471x	7.6x[3]	68.5	[5]				6	4				2	4	6
8	216x	2.8x[3]	93					50	50		15[6]	35		15	50
9				[5]				3	2		3				
10	403	35	259					3	3			3			3

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[2] This figure is for average thickness of Woodbine formation, which includes several "pay" sands interbedded with thick nonporous beds of shale and ashy shale.

[3] This figure is oil production divided by total feet of both oil and gas sand. No data are available to compute this figure for net oil sand.

[4] No commercial gas line serves this field; an average of 300 cu. ft. is produced with each barrel of oil but is used for fuel and for casinghead plants. Gas wells at the south end of the field are used by their owners for fuel for drilling and other lease purposes.

[5] A gas line was laid into these fields in December, 1934, and commercial production established early in 1935.

[6] Dry gas wells, for which there is no commercial market.

been equipped for artificial lifting but at the close of the year only 1025 wells were using such equipment; the majority of these were pumping. This is an increase of 419 over Jan. 1, 1934, when 606 wells were using artificial lift. The number of wells making water increased from 654 at the first of the year to 950 wells at the close, of which approximately 150 are thought to be from sources other than the producing horizon. Average bottom-hole pressure fluctuated during the year, falling and rising with the change in production rate. The net result for the year was a drop of 35 lb., with evidence that it was due for a further slow decline during 1935.

VAN FIELD

Drilling continued in this field with 53 new producers added. This brings the total producing wells in the field to 450. Total production during 1934 was 14,674,766, a decrease over 1933, when 17,225,296 bbl. was produced. Only minor extensions to the Woodbine producing area were made but a considerable area was added for shallow production beyond the limits of the Woodbine producing territory.

OTHER AREAS

The older productive areas in East Texas were extremely quiet with few wells added and no new horizons proved. The Long Lake field, discovered late in 1933, was proved to be essentially a gas reserve and only five wells had been completed in this field to the end of 1934. The

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1934				Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1934					Character of Gas, Approx. Average during 1934	
			Number of Wells					Average at End of		Gravity A. P. I. at 60° F.						
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Misc.	Initial	1933	1934	Maximum	Minimum	Weighted Average	Sulfur Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
1	2,366*y*	2,300*y*		33			*x*	*x*	*x*			40*y*	*y*	P		
2	4,700*y*[7]	1,000[7]					*y*	*y*	*y*						1000	*y*
3	4,650*y*[7]	1,000[7]					*y*	*y*	*y*						1000	*y*
4	3,666	3,632		21			650			40	38	38.5	0.24	P	1500	4
5	3,000	2,500	328	107			1,250±	1,165±	1,160±	36	33	35	0.8	P	1100	2.5
6	3,665	3,632	14,490	835*x*	180	10	*e*1,600*x*	*e*1,264	*e*1,231	41.6	38	39	0.25	M	1550	2.3
7	5,275	5,173	2				2,150	2,150	2,150			43		P	1035	0.25
8	4,085	3,822	34	1			*y*		*e*1,745			29	1.7	A	1090	0.5
9	5,825	5,695					2,250		2,250						*y*	*y*
10	2,013	1,995	3				700		700	23.8	23.8	23.8	0.1	P		

[7] Figures for top and bottom of producing horizons are from top of highest pay to bottom of lowest pay; six or more horizons are present in this interval.

structure found in northern Leon County late in 1933 was proved as a dry gas area by the completion of two additional gas wells during the year.

EXPLORATORY DRILLING

A large amount of exploratory drilling was carried on during 1934, resulting in a number of very promising prospects being condemned by the drill. Only one field of major significance, Cayuga, was uncovered by the wildcat drilling program. An oil well was completed in Cherokee County six miles southwest of Rusk during the summer of 1934. One dry hole was drilled as a south offset to the well and no additional drilling has been done. Possibilities of a major pool being developed by this discovery seem unlikely. The Rodessa gas field of Caddo Parish, Louisiana, was extended into Cass County, Texas, by the completion of a commercial gas well in the regular pay horizon of the field.

Cayuga Field.—The Cayuga field was opened in March, 1934, by the completion of Tide Water-Seaboard No. 1 Edens good for 656 bbl. per day of 29.3 gravity oil. A structure of several thousand acres is indicated by drilling during the year, and active exploitation was under way at the end of the year. Initial production of the wells ranges from 100 to 700 bbl. on a small choke. Gas is abundant and very careful drilling and setting of casing is required to complete producing oil wells. The field has proved itself during the year to be of major size but its ultimate oil recovery is limited by the thin section of oil sand encountered below thick gas sands, and above the established water level. The oil from this field is unusual, being black and having an asphalt base with a gravity

TABLE 1.—(*Continued*)

Line Number	Producing Rock					Structure^j	Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Name	Age^g	Character^h	Porosity^i	Net Thickness, Average Ft.			Name	Depth of Hole, Ft.
1	Tokio	CreU	S	20x	15	A	y	y	y
2	Nacatoch, Blossom, 2,300 ft., several sands to 3,300 ft., 4,700 ft.	CreU CreL	S, LS, SH	y	y	A	39	Sub-anhydrite of Lower Cretaceous	5,860
3	Nacatoch, Blossom, 2,300 ft.	CreU, CreL	S, LS, SH	y	y	A	16	Glen Rose of L Cretaceous	4,980
4	Woodbine	CreU	S, SH	25±	34±	Ds	43	Woodbine	4,648
5	Woodbine	CreU	S, H	25	268^2	Ds?	60	Trinity	7,501
6	Woodbine	CreU	S	25	28	MU	125	Woodbine	3,894
7	Woodbine	CreU	S	20	62	A		Middle Woodbine	5,468.5
8	Woodbine	CreU	S	24	75	A		Georgetown? (top of Lower Cretaceous)	4,666
9	Woodbine	CreU	S	11	30	A	1	Top of Georgetown	6,140
10	Reklaw	Eoc	S	y	12	A	5	Wilcox (Eocene)	3,870

under 30° Bé. This compares with "normal" Woodbine oil, which is brown, has a paraffin base and is 38° to 40° Baumé.

Kittrell Field.—A producing well of some significance but of no great importance was completed in September, 1934, by Boone et al. on Trinity State Bank land near the village of Kittrell, on the south line of Houston County. This well was completed at a depth of 2036 ft., flowing approximately 600 bbl. per day of 24.8 gravity oil. It is significant both because of its shallow depth and because it proves a new produc-

TABLE 2.—*Summary of Drilling Operations in East Texas District*

(Figures in body of tabulation represent number of holes.)

	County	Completed Prior to Jan. 1, 1935										Completed during 1934									Drilling or Incomplete at End of 1934	
		Dry and/or Near-dry Holes									Productive Wells	Dry and/or Near-dry Holes								Productive Wells		
		Total Depths, Ft.								Total		Total Depths, Ft.							Total			
		0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000		(For Details, See Table 1)	0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000		(For Details, See Table 1)	Within Fields	Exploratory
1	Anderson	17	23	14	31	18	14			117	88	3	1			2	6		12	54	1	2
2	Angelina	25	28	8	6	1				68			1						1			3
3	Bowie		4	22	18	1				45												1
4	Camp		1	3	3					7												
5	Cass	3	11	21	25	5				65	1			1	1	1			3	1		2
6	Cherokee	6	8	9	26	27	12			88	30				2	3	6		11	7		5
7	Collin	1	6	2	1					10												
8	Delta	2	2	3	8					15												
9	Fannin	3	3	7	3					16				1					1			
10	Franklin		5	2	12					19					2				2			
11	Grayson	28	33	17	5	1	1			85	7	1		1					2			
12	Gregg	1	6	7	69	4				87	7,585		3		19				22	1,762	36	1
13	Harrison	6	27	18	7	2				60	208				1				1			4
14	Henderson	5	10	5	23	30	2			75					1	5	1		7			2
15	Hopkins	4	5	4	22	5				40						1			1			1
16	Houston	1	7	16	7	3	1	1		36	4		1	6	3			1	11	4	1	2
17	Hunt	1	9	7	26	2				45		1			5				6			4
18	Kaufman	3	5	15	29					52			1						1			2
19	Lamar	4	4	8	2	1				19				1					1			
20	Leon	1	4	4	4	1	3	3		20	3	1		1			1	1	4	2		
21	Madison	3	3	4				2		12				2				2	4			2
22	Marion		4	46	16	1				67	34			1	1				2			2
23	Morris		1	4	4	4				13						3			3			1
24	Nacogdoches	2	7	7	15	11	1			43					1	2			3			2
25	Panola		2	35	13					50	350			7					7	3	6	1
26	Rains		3	2	5	7				17			1			2			3			1
27	Red River	1	18	17	4	1				41			2	2					4			1
28	Rockwall				1					1												
29	Rusk	2	9	13	66	8				98	6,054		1	1	11	1			14	1,434	34	4
30	Sabine	1	5	6	4	2				18												
31	San Augustine	17	4	4	1	1				27			2						2			1
32	Shelby	2	7	26	34	5	1	1		76	6				3				3			2
33	Smith	7	5	13	25	24	3			77	821		1		7	5	1		14	192	4	3
34	Titus	3	1	5	9	3			1	22												
35	Trinity	2	4	2	3	1				12					1				1			2
36	Upshur	1	6	4	69	8		1		89	1,067		2		23				25	281	6	
37	Van Zandt	2	22	24	53	12	2	1	1	117	424		9	4	3	2			18	27	9	5
38	Wood	4	9	5	9	10	4			41						1	2		3			
	Total	158	311	409	658	199	44	9	2	1,790	16,682	6	25	28	84	28	17	4	192	3,767	97	56

tive horizon. The exact correlation is in some dispute, but the prevailing opinion is that the oil comes from the Reklaw formation near the base of the Mt. Selman group of Eocene age. It is not expected to become a field of importance, as drilling by the end of the year had defined the field on three sides and had limited its ultimate size to a few hundred acres. The two additional wells completed by the end of the year were smaller than the discovery and indicated irregular sand conditions.

SUMMARY AND OUTLOOK FOR 1935

Drilling in the East Texas field will perhaps continue to be active during 1935, but the probability is that fewer producers will be completed in 1935 than in 1934. Active development will continue in the Cayuga field and the limits should be established during the year. It is anticipated that wildcat drilling for Woodbine production will decrease sharply during 1935. Production from the East Texas pool should continue at approximately its rate during 1934 and may even increase this figure if the market will support additional oil. Enforcement of proration in the field will perhaps suffer continued vicissitudes during 1935 but should control the excess oil production within the average figure for 1934 and may well decrease the amount of such oil produced.

ACKNOWLEDGMENTS

The data used in this report were obtained from many sources, including Federal and State statistics, association and institute publications and trade journals. Accurate statistics for both oil and gas production are in some cases very difficult to obtain. This comes from the reluctance of operators to reveal information which may be used against them by State or Federal regulatory bodies or by unscrupulous persons as the basis of lawsuits. Where there is a large amount of "hot oil" being produced, as in East Texas, there is great discrepancy between the various estimates as to the gross production of the field. Figures contained herein are the best average that can be obtained of these various figures. Thanks for information and assistance are due to many persons but especially to L. T. Barrow, Humble Oil & Refining Co., for data on Boggy Creek, Roy T. Hazard, Gulf Refining Co., for data on the Caddo field, C. R. McNight, Arkansas Gas Co., for data on Waskom and Bethany fields, and to J. W. Kisling and J. S. Kirkendall, Amerada Petroleum Corporation, who compiled all statistical data.

Oil and Gas Development on the Texas Gulf Coast during 1934

By W. B. McCarter*

(New York Meeting, February, 1935)

Broadly speaking, the year 1934, one of the most active in the history of the Coast, has been both disappointing and revealing. Of the 18 new oil-producing areas, only two have shown the qualities of a first class oil field. Many of the new areas are discouraging for the horizons exploited, because of close association of gas and salt water, and the absence of any appreciable oil zone. In spite of amply fulfilling the expectations of drilling and geophysical development, the year has fallen far short of the results that normally should be expected from such a campaign.

In 1934, the Cockfield zone has been disappointing because its exploration down the dip from the Conroe and Tom Ball fields revealed only such distillate fields as Splendora, Eureka, and the great gas-sand thickness at Katy. The zone proved good at Raccoon Bend. Newer Oligocene and Frio fields in Texas, with the exception of Hastings, were also disappointing, as Van Vleck and Old Ocean attest. The discovery at Dickinson is not startling. The development of Hastings, Tom Ball, Dickinson and the deep zone at Raccoon Bend will be slow. A new strip of prospective territory of minor importance lying inland from the Conroe trend was opened by the Kittrell discovery.

During the year 206 unproductive wildcats were drilled on the Texas Coast, compared with 207 during 1933 and 141 during 1932. During 1934, there were 835 oil and gas wells and 229 dry holes drilled in proved fields, in contrast with 1100 in 1933 and 512 in 1932.

The past year's production was actually 60,868,260 bbl., or 2,020,764 bbl. less than in 1933. The present annual rate of Texas Gulf Coast production is about 61 million barrels per year. The daily Texas Coast production decreased 5537 bbl., or 3.2 per cent, during the year. The total daily production at the end of the year was 173,598 bbl. Eighteen wildcats opened up new oil and gas pools during 1934, so that there are now 78 active pools and 3753 producing oil wells. The production of the average well is 45 bbl. per day. The price of crude oil was almost uniform in 1934,

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TABLE 1.—*Oil and Gas Production in Texas Gulf Coast*

Line Number	Field, *County*	Age in Years to End of 1934	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934[5]	Daily Average during Nov., 1934
1	Spindletop[1], *Jefferson*	34	430			430	121,230,433	1,157,944	1,149,663	2,961
2	Shallow	34	280			280	50,731,888	140,000	138,071	372
3	Deep	10	150			150	70,498,545	1,017,944	1,011,592	2,589
4	Saratoga[1], *Hardin*	34	500			500	27,410,708	298,235	290,366	812
5	Sour Lake[1], *Hardin*	33	765			765	76,816,392	476,017	508,628	1,334
6	Batson[1], *Hardin*	32	490			490	36,333,795	207,835	243,003	762
7	Big Hill[1], *Matagorda*	31	15	Past Prod		15	210,906			
8	Humble[1], *Harris*	30	2,320			2,320	118,896,720	1,786,620	1,243,074	3,484
9	Shallow	30	2,110			2,110	107,752,247	935,349	716,709	
10	Deep	6	210			210	11,144,473	847,275	526,365	
11	North Dayton[1], *Liberty*	30	55			55	2,149,681	56,630	59,116	200
12	Shallow	30	25			25	800,000			
13	Deep	8	30			30	1,349,681	56,630	59,116	200
14	Hoskins Mound, *Brazoria*	28	10	Past Prod.		10	31,755			
15	Goose Creek[2], *Harris*	27	910			910	73,230,018	1,159,619	1,208,428	3,118
16	Markham[1], *Matagorda*	27	185			185	4,879,880	375,339	401,979	1,406
17	Orange[2], *Orange*	22	400			400	31,485,087	333,643	279,686	750
18	Brenham[1], *Austin, Washington*	20	55			55	325,068	11,849	11,757	27
19	Damon Mound[1], *Brazoria*	20	270			270	8,814,075	260,519	208,623	499
20	West Columbia[1], *Brazoria*	20	270			270	77,801,107	1,198,316	1,033,442	2,704
21	Barbers Hill[1], *Chambers*	19	500			500	44,549,140	8,026,038	6,836,093	19,905
22	Shallow	19	70			70	1,745,214			
23	Deep	7	430			430	42,803,926	8,026,038	6,836,093	19,905
24	Hull[1], *Liberty*	17	690			690	77,660,656	2,006,200	3,476,876	7,479
25	Shallow	17	615			615	75,105,615	1,617,302	1,310,733	3,825
26	Deep	2	75			75	2,555,041	388,898	2,166,143	3,654
27	Blue Ridge[1], *Fort Bend*	16	325			325	9,339,530	287,949	310,775	854
28	Pierce Junction[1], *Harris*	14	312			312	28,045,692	1,559,047	1,204,102	3,527
29	Edna[2], *Jackson*	14			125	125				
30	High Island[1], *Galveston*	13	200			200	8,510,145	2,467,904	2,768,798	6,821
31	Stratton Ridge[1], *Brazoria*	13	25	Past Prod.		25	12,214			
32	Big Creek[1], *Fort Bend*	12	200			200	8,237,634	408,801	361,450	855
33	Big Hill[1], *Jefferson*	12	10	Past Prod.		10	13,853			
34	Hockley[1], *Harris*	12	10			10	16,656	13,128	2,590	3
35	Kingsville, *Kleberg*	12	90		175	265	616,597	25,844	24,261	64
36	Mathis, *San Patricio*	12			100	100				
37	Boling[1], *Fort Bend, Wharton*	10	200			200	4,530,876	125,037	140,421	423
38	South Liberty[1], *Liberty*	10	235			235	14,628,465	260,627	180,455	455
39	Fannett[1], *Jefferson*	9	65			65	1,348,802	145,628	195,370	483
40	Nash[1], *Brazoria, Fort Bend*	9	120			120	1,622,932	30,048	12,147	43
41	Orchard[1], *Fort Bend*	9	145			145	2,682,240	413,623	453,390	1,141
42	Allen[1], *Brazoria*	8	10			10	74,665	3,044	3,910	21
43	Clay Creek, *Washington*	7	265			265	2,891,412	321,103	263,830	803
44	Raccoon Bend, *Austin*	7	2,109		785	2,894	13,425,784	1,501,449	1,480,826	4,231
45	Shallow	7	1,371			1,371	13,295,768	1,501,449	1,350,810	3,479
46	Deep	1	1,296			1,296	130,016		130,016	752
47	Refugio[2], *Refugio*	7	1,877		2,720	4,597	30,386,270	2,123,414	1,418,849	4,372
48	Shallow (Heavy)		1,025			1,025	19,856,435	1,079,086	679,891	1,651
49	Deep (Light)		852			852	10,529,835	1,044,328	738,959	2,721
50	Sugarland, *Fort Bend*	7	1,163			1,163	21,036,782	2,538,313	2,185,659	6,000
51	Esperson[2], *Liberty*	6	320			320	3,114,587	485,795	446,445	1,512
52	Hankamer[2], *Liberty*	6	180			180	2,980,521	539,283	376,050	1,192
53	Lost Lake, *Chambers*	6	65			65	688,346	79,821	68,706	235
54	Port Neches[2], *Orange*	6	250			250	2,875,158	388,077	562,676	1,602
55	Rockland, *Jasper*	6	20			20	29,344	3,967	2,718	10
56	Agua Dulce, *Nueces*	5		1,000	3,653	4,653	133,134	8,099	103,027	570
57	Danbury, *Brazoria*	5	50	Past Prod.[4]		50	3,612		3,612[4]	
58	Mykawa, *Harris*	5	90			90	437,442	98,199	154,619	878
59	Moss Bluff, *Chambers, Liberty*	5	10	Past Prod.		10	179,235	6,065		
60	Pettus District, *Bee*	5	2,520			2,695	8,162,132	1,211,928	1,057,730	3,947
61	Pettus Town Site	5	825			825	7,035,240	917,814	578,641	1,623
62	North Pettus		400			400	838,580	218,405	352,180	1,580
63	Normanna		20			20	43,058	7,612	4,562	
64	Tuleta, West Tuleta		825			825	243,104	68,097	120,197	717
65	Northwest Tuleta	1	300			300				

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[a] Footnotes to column headings and explanation of symbols are on page 249.

[1] In salt dome fields of piercement type, maximum and minimum depths of producing horizons are shown.

[2] Fields of non-piercement type without uniform sands, having multiple lenticular sands, are treated as in footnote 1

[4] Shallow Miocene oil locally used for fuel in drilling.

[5] Production for December estimated.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age in Years to End of 1934	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934[5]	Daily Average during Nov., 1934
66	Kimball		50			50	2,150		2,150	27
67	Caesar	1	100		175	275				
68	Saxet[2], *Nueces*	5		650	4,362	5,012	2,270,327	876,063	731,854	2,249
69	Slick, *Goliad*	5	25			25	53,353	10,504	1,064	
70	White Point[2], *San Patricio*	5		20	3,865	3,885	60,879	16,200	9,623	32
71	Lucas, *Live Oak*	4		500	3,525	4,025	82,964	19,614	28,385	166
72	Manvel, *Brazoria*	4	1,520			1,520	1,816,411	587,719	997,958	4,073
73	Thompsons, *Fort Bend*	4	3,635			3,635	14,115,392	4,149,140	4,209,444	11,880
74	Ariola[2], *Hardin*	3	100			100	663,432	191,219	464,583	838
75	Buckeye, *Matagorda*	3	500			500	454,818	272,511	76,852	164
76	Conroe, *Montgomery*	3	17,318			17,318	41,242,037	21,518,456	17,138,137	38,005
77	Keeran[2], *Victoria*	3	250		20	270	242,342	96,062	100,822	313
78	MacFadden, *Victoria*	3	10		845	855	27,740		6,235	81
79	O'Connor, *Refugio, Victoria*	3	250			250	133,118	21,105	109,438	353
80	Pledger, *Brazoria*	3		20	1,100	1,120	17,006	15,906	1,100	
81	Garwood, *Colorado*	2	10	0	Past Prod.	10	2,024	2,024		
82	Greta, *Refugio*	2	4,779			4,779	5,143,371	1,216,624	3,926,747	12,924
83	Livingston, *Polk*	2	885			885	1,144,685	412,267	732,023	2,222
84	Seeligson, *Jim Wells*	2	200			200	4,500	1,400	3,100	14
85	Tomball, *Harris*	2	9,118		4,927	14,045	1,224,994	246,657	978,337	3,792
86	Ace[3], *Polk*	1	50			50	5,768		5,768	53
87	Angelita, *San Patricio*	1	100			100	23,080		23,080	48
88	Brookshire, *Waller*	1	50			50	2,640		2,640	26
89	Cleveland, *Liberty*	1	400			400	178,763	789	177,974	400
90	Raisin[2], *Victoria*	1		300	365	665	16,952		16,952	125
91	Dickinson, *Galveston*	1	100			100	6,275		6,275	80
92	Eureka[3], *Harris*	1	100			100	1,360		1,360	41
93	Hastings, *Brazoria*	1	100			100				
94	Kittrell, *Houston*	1	160			160	36,844		36,844	203
95	Louise, *Wharton*	1	1,000			1,000	185,300	3,162	182,138	736
96	Dinero, *Live Oak*	1	100			100	16,168		16,168	102
97	Old Ocean[3], *Brazoria*	1	100			100	10,740		10,740	244
98	Port Lavaca[3], *Calhoun*	1	100			100	3,100		3,100	
99	Sinton, *San Patricio*	1	120	20		140	5,775		5,775	50
100	Splendora[3], *Montgomery*	1	100			100	676		676	
101	Tomoconnor, *Refugio*	1	2,000			2,000	33,097		33,097	356
102	Vanderbilt[3], *Jackson*	1	100			100	65,326		65,326	165
103	Bay City[3], *Matagorda*	1	100			100	13,495		13,495	84
104	Total		62,111	2,510	26,742	91,363	937,154,233	62,058,419	60,850,360[5]	165,302

[3] Distillate and gas field.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.		Depth[1,2], Ft.				Number of Oil and/or Gas Wells							
			Range of Production		Weighted Average			During 1934		At End of 1934				
	Per Acre to End of 1934[5]	Per Well Daily during Nov., 1934	Shallowest	Deepest	Bottoms of Productive Wells	To Top of Productive Zone	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	269,400	18	750	5,900	1,610		1,343*x*		*y*	*y*	167			167
2	181,185	5	750	1,200	1,000		1,003*x*		*y*	*y*	78			78
3	414,697	29	2,920	5,900	3,400		341*x*		*y*	*y*	89			89
4	54,821	4	200	2,000	1,000		739*x*		*y*	*y*	197			197
5	100,414	7	230	4,000	900		775*x*	10	*y*	*y*	181		1	182
6	74,151	5	1,000[6]	1,500	1,250		976*x*	2	*y*	*y*	163			163
			200[7]	4,950	850									
7	14,060	0	850[6]	875	862		3		*y*	*y*				
			2,000[7]	2,100	2,050									
8	51,249	17	700	5,400	1,800		1,664*x*	6	40*y*	*y*	211			211
9	51,066		700[7]	3,400	1,700		1,591	6	*y*	*y*	69			69
			1,150[6]	1,250	1,200									
10	53,067		3,800	5,400	4,800		73	0	*y*	*y*	42			42
11	39,085	20	425	5,180	3,800		62		*y*	*y*	10			10
12	32,000		425	2,900	1,200		52		*y*	*y*				
13	44,989	20	4,000	5,183	4,800		10		*y*	*y*	10			10
14			*x*	*x*	*x*		1		*y*	*y*				
15	80,473	35	1,050	4,500	2,800		860	12	12*y*	3*y*	89			89
16	26,378	52	530	3,800	1,500		125	5	2*y*	*y*	27			27
17	78,712	14	2,850	5,200	4,000		313	2	*y*	*y*	53			53
18	5,910	1	190	275	225		62		5*y*	*y*	29			29
19	32,645	16	1,350	3,800	2,700		120	5	5*y*	*y*	32			32
20	288,152	70	660	4,600	3,200		233	1	3*y*	*y*	37			37
21	89,098	133	830	6,704	4,500		351	35	*y*	4*y*	153			153
22	24,931		830	4,100	2,300		42		*y*	*y*				
23	99,544	133	4,000	6,704	5,200		309	35	*y*	4*y*	153			153
24	112,552	35	900	5,300	2,900		684	58	3*y*	*y*	212			212
25	122,123	27	900	4,600	2,200		614	9	3*y*	*y*	141			141
26	34,067	51	3,950	6,150	4,650		70	49	*y*	*y*	71			71
27	28,737	23	1,850	5,000	3,600		160	4	1*y*	*y*	37			37
28	89,890	59	3,300	5,900	4,300		208	12	11*y*	*y*	60		2	62
29			2,640	5,370	3,400		11		*y*	*y*			*x*	*x*
30	42,551	162	149[6]	200	4,325		65	7	2*y*	*y*	42			42
			2,700[7]	6,200										
31					4,360		4							
32	41,188	39	700[6]	800	3,850		66	3	*y*	*y*	22			22
			2,650	4,200										
33	1,385		1,500	5,958	2,500		3		*y*	*y*				
34	1,666	3			2,250	2,220	3		*y*	*y*	1			1
35	6,851	9			2,350	2,050	18		*y*	*y*	7		*y*	*y*
36					2,385	2,375	5		*y*	*y*			*x*	*x*
37	22,654	6	420	4,000	1,375		139	3	*y*	*y*	72			72
38	62,249	10	510	3,900	3,500		278	2	3*y*	5*y*	43			43
39	20,750	69	3,260	5,800	4,660		13		*y*	*y*	7			7
40	13,524	43	3,700	5,677	4,300		24				1			1
41	18,498	114	2,280	4,000	3,750		24	2			10			10
42	7,466	21	4,350	5,384	5,030		5				1			1
43	10,926	24	985	1,375	1,250		45	7			34			34
44	6,366	42			1,020[8]	1,010	162	17		22	102		3	103
					4,100	3,125								
45	9,678	39			3,150	3,125	148	3		22	88			88
					3,475	3,450								
46	100	58			4,100	4,000	14	14			14			14
47	16,189	44	3,600	6,500	2,300[8]	1,850	380	20	*y*	*y*	97		*y*	*y*
					5,000									
48	19,372	34			3,700	3,600	271	3	*y*	*y*	48*y*		*y*	*y*
49	12,359	54	5,000	6,500	6,000		109	17	*y*	*y*	50*y*		*y*	*y*
50	18,088	176	3,200[8]	3,400	3,575		69			27	34			34
			3,400	3,800										
51	9,733	52	2,185	4,100	2,970		38	3			29			29
52	16,558	238	2,675	4,891	3,975		17	2	4	6	5			5
53	10,590	29	2,390	2,840	2,830		11	0	1		8			8
54	11,501	123	3,150	5,911	3,830		15	3			13			13
55	1,467	3			1,275	1,260	8				3			3

[6] Cap. rock. [7] Sand. [8] Gas.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.		Depth[1,2], Ft.				Number of Oil and/or Gas Wells						
			Range of Production		Weighted Average			During 1934		At End of 1934			
	Per Acre to End of 1934[b]	Per Well Daily during Nov., 1934	Shallowest	Deepest	Bottoms of Productive Wells	To Top of Productive Zone	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
56	133	71			2,005[8]	1,998	25	11			[10]	14	y	y
					4,820[9]	4,804								
57	72				1,579	1,572	2	1[4]		1				
58	4,862	146			4,880	4,840	9	4			[illegible]			6
59	17,923		5,666	5,860	830[6]	800								
					5,800[7]		5							
60	3,239		3,088	4,150	3,850		183	65	y	y	97		y	y
61	8,528	37			3,900	3,860	91				42			42
62	2,096	61			3,664	3,655	38	28		4	26		y	y
63	2,153				3,634	3,613	4	1			1			1
64	295	31			T. 4,165	4,152	12							
					W.T. 3,930	3,907	26	26			23			23
65					3,884	3,880	1	1			1			1
66	43	27			3,553	3,546	2	1			1			1
67					3,106	3,088	9	8			3		y	y
68	3,493	78	2,742	5,235	2,360[8]	2,340	72	9	y	y	29		y	y
					4,475									
69	2,134				4,225	4,211	3			2	1			1
70	3,044	32	1,850[8]	3,125	2,375									
					4,902[9]	4,880	35				1		y	y
71	166	28			2,090[8]	2,020								
					3,533	3,500								
					5,287	5,200	32	5		2	6		y	y
72	1,195	97			4,016	3,990	47	36		3	42		y	y
					5,160	5,000								
73	3,883	71			5,300	4,925	178	27		5	167			167
74	6,634	140	4,100	4,700	3,000		9	5		3	6		y	y
75	910	82			7,926	7,831	2				2			2
76	2,381	46			5,150	5,000	843	158			827			827
77	969	156	5,130	5,851	5,574		6	2		2	2		y	y
78	2,774				3,742[8]	3,737	9	3		1	1		y	y
					6,187[9]	6,171								
79	532	50			3,100	3,075	10	6	y	y	7			7
80	850				6,800	6,600	6	4		5				
81			4,062	6,203	5,132		2							
82	1,076	70			3,508	3,470	192	101	y	y	180			180
					4,398	4,350								
					5,918	5,900								
83	1,293	63			4,330	4,260	36	23		1	35			35
84	23	14			3,265	3,248	4	3		3	1			1
85	134	35			5,555[8]	5,375	130	103	y	y	107		y	y
					5,575[9]	5,555								
86	115	53			4,846	4,828	1				1			1
87	230	48			5,380	5,370	2	2		1	1			1
88	53	53			2,978	2,955	1	1			1			1
89	447	80			5,840	5,832	5	4		3	2			2
90	57	21	2,220	4,460	3,160		11	10		y	6		y	y
91	63	40			8,000[8]	7,783	2	2			2			2
					8,020	8,000								
92	14	41			7,695	7,662	1	1			1			1
93					6,003	5,980	1	1			1			1
94	230	101			2,055	1,975	4	4			4			4
95	185	105			5,150	5,140	9	7	2		7			7
					6,463	6,450								
					7,173	7,138								
96	162				4,376	4,370	1	1			1			1
97	107	244			8,651	8,629	1	1			1			1
98	31				6,158	6,148	1	1			1			1
99	41	15			5,530	5,520	4	4		1	3			3
100	7				5,841	5,816	1	1		1				
101	16	178			5,848	5,835	4	4		1	3			3
102	653	165			5,282	5,262	2	2		1	1			1
103	134	42			7,075	7,020	2	2			2			
104							11,974	835	y	y	3,744	14	y	y

[9] Oil.

[10] Total included in "Producing Oil and Gas" column.

TABLE 1.—(*Continued*)

Line Number	Oil Production Methods at End of 1934						Pressure, Lb. per Sq. In.[13,e]			Character of Oil Approx. Average during 1934					Character of Gas Approx. Average during 1934	
	Number of Wells							Average at End of		Gravity A.P.I. at 60° F.						
	Flowing	Pumping	Gas-lift	Air-lift	Miscellaneous	Injection into Reservoir[d]	Initial	1933	1934	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
1	2	165					x		50	41.7	23	28	0.24	A	x	
2		78					x					22				
3	2	89					400x		50			30				
4	1	196				2	x			22.0	16	20	x	A		
5	3	178					x			31.0	16	22	0.94	A	x	x
6	1	162					x		125	29.8	20	27.7	x	A	x	x
7							x			x	x	x	x	A	x	
8	2	209					x		75	45.0	17	x	0.108	A		
9		69					x			36.0	17	x				
10	2	40					315			45.0	38	41				
11		10					400x			41.5	22	28	0.12	A		
12							x					24				
13		10					400					36				
14							x					x	x	A		
15		86		3			x			36.0	19.2	23	0.19	A		
16	6	21					x		325	27.6	23	23.2	0.21	A		
17		53					x			27.4	20.4	23.8	0.18	A		
18		29								19.0	14	17	x	A		
19		32					x			33.0	21	26	0.372	A		
20	6	28		3			x		93	32.0	18	28	x	A		
21	49	102	2				296	260	309	34.7	17	25	0.214	A		
22																
23	49	102	2				296	260	309							
24	14	198					x	410	85	41.0	17	32.7	0.28	A		
25		141					x			34.0	17	24				
26	14	57					5,30x	410	85	41.0	36	38				
27	4	33					3,85x		75	45.0	20	26	0.25	A		
28	10	50					3,55x	126	195	41.5	21	27.6	0.173	A		
29							1,100x	x	x						y	y
30	20	21		1			527x	345	362	39.0	23	33	x 0.28	A		
31							x					29	x	A		
32	1	21					400x		400	42.7	19.5	28	x	A		
33							x					x	x	A		
34		1					40x			37.0	22	32	x	A		
35		7					x					19.2	0.14	A		
36							935x	x	x						y	y
37	36	37		2			x		10	33.7	21.3	28.3	0.41	A		
38	3	40								47	20.5	24	0.18	A		
39		7					540			37	26	30	x	A		
40		1					800			24	20	22	x	A		
41	4	6					375	40	218	41.4	22.1	28.3	x	A		
42	0	1					200			41.3	28.3	34.3	0.105	A		
43	9	24					350x	x	150	27	23	26	0.36	A		
44	15	87				23	300			38	16	28	0.18	A	1,000	0.8
45	2	87				23	275			32	16	28				
46	13						e1,760		e1,755	38	32	34				
47	56	2	39				1,200	350	874	60	21	31	0.14	A		
48	y	y	y				550		y			23	0.10	A		
49	y	y	y				1,700		y			39	0.169	A		
50	32		2			1	e1,330	e1,372	e1,379			28	0.31	A		
51	2	27					100		275	32	21	24	0.26	A		
52	5						424	55	90	26	15.7	23.4	0.33	A		
53		8					490			23.4	18	22.4	0.22	A		
54	1	12					155		1,000	26.5	19.6	22.3	0.26	A		
55	0	3										21	0.26	A		
56	14						Gas 790[14] Oil 1,650	1,575	1,320 1,320			54y	0.022	M		
57							x						x	A		
58	2	4					290		350	30.5	27	28.2	0.141	A		
59							280					29.7	0.21	A		
60	51	21	20		5[11]							47	x	M		

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[11] Jetting.

[13] Refers to working pressures only, unless otherwise noted.

[14] "Rock" pressure.

TABLE 1.—(*Continued*)

Line Number	Oil Production Methods at End of 1934						Pressure, Lb. per Sq. In.[13,e]			Character of Oil Approx. Average during 1934					Character of Gas Approx. Average during 1934	
	Number of Wells					Injection into Reservoir[d]	Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
	Flowing	Pumping	Gas Lift	Air-lift	Miscellaneous			1933	1934	Maximum	Minimum	Weighted Average				
61	3	21	15		3[11]		236	30	125	49	45	47	0.05	M		
62	21		5				*y*		410	51	45	47	*x*	M		
63	1						150		100			40	*x*	M		
64	2				2[11]		534		150	51	45	47	*x*	M		
	19						792		784							
65	1						370		370			*y*	*x*	M		
66	1						100		100			35*y*	*x*	M		
67	3						Gas 1,160[15]		990[14]			*y*	*x*	M		
							Oil 315		235							
68	24				5[11]		1,325	620	1,240	26	23	25	0.18	M		
							745		646							
69	1						550	65	1,050[8]			48.6	0.044	M		
									465							
70	1						Gas 764	*y*	477			31	0.094	M		
							Oil 2,000		1,740							
71	4	1			1[11]		Gas 874[14]		340	50	24	36	*x*	A		
							Oil 1,400		1,225					M		
72	37	5					478	339	385	33	22.1	26	*x*	A		
73	162	5					750	568	560			25	0.20	A		
74	1	5					440	542		42	27	34	0.12	A		
75		2					1,045					37	0.07	A		
76	822	5					e2,275	e2,113	e2,087			38	0.05	M	1,128	1
77	1	1					Gas 2,400	750	2,200	48	28	37	*x*	A		
							1,450		1,450							
78	1						1,725		1,638			47	0.16	A		
79	5		2				365		196				0.16	A		
80							2,450	2,450				55.8	*x*	M		
81							1,225					44	*x*	M		
82	175				2[11]							S. 24.5				
					3[12]		633	777	431			D. 38	0.20	A		
83	30	5					700	556	561			40.7	0.053	M		
84	1						*x*		1,100			22.8	*x*	A		
85	107						e2,490	e2,406	e2,417	45.4	37.5	41	0.041	M		
86	1						1,400		1,250			64.9	*x*	M		
87	1						1,140		450			35*y*	0.132	A		
88	1						100		100			24	*x*	A		
89	2						1,350	940	1,000			40	*x*	M		
90	4	1			1[11]		530[14]		350			22	*x*	A		
91	2						1,250		1,250	54	37.6		0.067	M		
92	1						2,400		2,400			54.6	*x*	M		
93	1						2,175		2,175			38	*x*	A		
94	4						360		225			24	0.19	A		
95	7						1,000		980	63	24	28	*x*	A		
96	1											44.5	*x*	A		
97	1						1,650		1,600			67	*x*	M		
98	1						500					61	*x*	M		
99	3						2,200		2,100			50	*x*	A		
100							2,000					65	*x*	M		
101	3						667		392			36	0.015	A		
102	1						500		200			32	0.128	A		
103	2						1,700		1,235	56	40	48	*x*	M		
104	1,757	1,912	65	9	17	26										

[12] Jamming.

[15] Casing pressure.

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
		Pre-Ter							
1	Cap rock-Plio	Plio	L.SH	Cav					
	Mio	Mio	Ss	Por	x	D[illegible]	1,25x	Vicksburg	6,654
	Mid. Olig-Frio	Olig							
		Pre-Ter		Cav					
2	Cap rock-Plio	Plio	L.SH	Por	[illegible]		18x		
3	Mio-Mid. Olig-Frio	Mio	Ss	Por	69x		107		
		Olig							
4	Lagarto	Mio-Plio	Ss, L						
	Mid. Olig	Olig							
	Cap rock	Pre-Ter		Por	x	Ds	214x	U. Saline Bayou	6,275
5	Cap rock-Plio-Mio	Plio-Mio							
	Mid. Olig	Olig-Eoc	L.Ss	Cav					
	Jackson-U. Saline Bayou	Pre-Ter	SH	Por	x	Ds	188	U. Saline Bayou	7,012
6	Cap Rock-Lissie-Lagar	Plio-Mio	L, Ss	Por	x	Ds	74x	U. Saline Bayou	5,204
	Mid. Olig-Saline Bayou	Olig-Eoc		Cav					
		Pre-Ter							
7	Cap rock	Pre-Ter	L	Cav	x	Ds	5	x	x
	(x) Mio	(x) Mio	x	Por					
			S						
8	Cap rock-Mio-Olig	Pre-Ter	LS	Cav					
	Jackson-Cockfield	Mio-Olig	SH	Por	60x	Ds	795	L. Saline Bayou	8,181
	Saline Bayou	Eoc							
		Pre-Ter		Cav					
9	Cap rock-Mio-Olig	Mio-Olig	LS	Por	x				
10	Mid. Olig	Olig							
	Jackson-Cockfield		SH	Por	400				
	Saline Bayou	Eoc							
11	Miocene-Plio	Mio-Plio	Ss						
	Frio-Vicksburg	Olig	SH	Por	32x	Ds	107	U. Saline Bayou	5,700
12	Plio-Mio	Plio-Mio	Ss	Por	x				
13	Mio	Mio	SH		32x				
	Frio-Vicksburg	Olig							
14	Cap rock (y)	Pre-Ter	S	Cav	x	Ds	x	x	x
15	Plio-Mio	Plio-Mio	SH	Por	38x	D	259	McElroy	6,855
	Mid. Olig	Olig	Ss						
	Frio-Vicksburg								
16	Cap rock	Pre-Ter	L.	Cav	46x	Ds	134	Vicksburg	6,044
	Plio-Mio	Plio-Mio	SH	Por					
	Mid. Olig	Olig	Ss						
17	Plio-Mio	Plio-Mio	Ss						
	Mid. Olig, Frio	Olig	SH	Por	30x	D	87	Frio	6,158
18	Oakville	Mio							
	Cockfield	Eocene	SH	Por	10x	Ds	58	Sparta	3,572
19	Mio								
	Mid. Olig	Mio							
	Vicksburg	Olig	SH	Por	43x	Ds	171	Vicksburg (y)	7,583
20	Plio-Mio	Plio							
	Mid. Olig	Mio	Ss	Por	250x	Ds	165	Vicksburg	6,306
	Frio-Vicksburg	Olig							
21	Plio-Mio	Plio-Mio					3[16]		
	Frio	Olig	Ss	Por	75x	Ds	128	McElroy	8,148
22	Plio-Mio	Plio-Mio	Ss	Por	42x				
23	Mio	Mio							
	Frio	Olig	Ss	Por	80x				
24	Plio-Mio	Plio-Mio							
	Mid. Olig	Olig	S				5[16]		
	U. Saline Bayou	Eoc	SH	Por	65x	Ds	204	L. Saline Bayou	6,676
25	Plio-Mio	Plio-Mio							
	Mid. Olig	Olig	S	Por	60x		198		
26	U. Saline Bayou	Eoc	SH	Por	430x		[illegible]		
27	Mio								
	Mid. Olig	Mio					5[16]		
	Frio	Olig	SH	Por	60x	Ds	104	Vicksburg	6,024
28	Mio								
	Mid. Olig	Mio					56[16]		
	Vicksburg	Olig	Ss	Por	44x	Ds	156	Vicksburg	6,194
29	Mio	Mio							
	Frio	Olig	S	Por	30	D	[illegible]	Frio	6,425

[16] Number of dry holes drilled prior to commercial oil or gas discovery.

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
30	Plio-Mio Mid. Olig	Plio-Mio Olig	S SH	Por	50x	Ds	18^{16} 108	Mid. Olig	6,275
31		y	S	Por	10x		25^{16}, x 74	Mid. Olig	7,624
32	Plio-Mio Mid. Olig Frio	Plio-Mio Olig	SH	Por	54x	Ds	2^{16} 55	Claiborne	3,867
33	Mio-Plio	Mio-Plio	S	Por	10x	Ds	55	Mio	6,010
34	Cap rock Frio	Pre-Ter Olig	SH	Cav Por	30x	Ds	35^{16} 64	Caddell	7,063
35	Lagarto	Mio	S	Por	20x	D	49	Frio	6,922
36	Mio	Mio	S	Por	10	ML	6	McElroy	5,526
37	Cap rock Mid. Olig Frio	Pre-Ter Olig	L SH	Cav Por	60x	Ds	9^{16} 252	Mid. Olig	5,546
38	Mio-Mid. Olig Jackson U. Saline Bayou	Mio Olig Eoc	SH Ss	Por	40x	Ds	29^{16} 115	CreU in Cap rock U. Saline Bayou On Flank	2,022 5,176
39	Mio Mid. Olig, Frio	Mio Olig	SH	Por	38x	Ds	10^{16} 33	Vicksburg (y)	6,661
40	Mio Mid. Olig	Mio Olig	S SH	Por	60x	Ds	11^{16} 39	Vicksburg	6,232
41	Mio Mid. Olig	Mio Olig	SH S	Por	28	Ds	4^{16} 25	U. Saline Bayou	6,757
42	Mio	Mio	SH	Por	100	Ds	21^{16} 30	Mio	5,958
43	Claiborne Wilcox	Eoc	SH	Por	120	Ds	1^{16} 40	Wilcox	5,517
44	Oakville (Gas) Jackson Cockfield	Mio Eoc	Ss	25x	10 63	D	16^{16}, 6^{17} 58	L. Saline Bayou	6,563
45	Whitsett McElroy	Eoc	Ss	25x	43	D	48		
46	Cockfield	Eoc	Ss	25x	56	D	15		
47	Lagarto (Gas) Mio Frio	Plio Mio Olig	SH	Por	30x	D	32^{16}, 57^{17} 94	McElroy	9,134
48	Mio	Mio	SH	Por	30x	D	64		
49	Frio	Olig	SH	Por	30x	D	30		
50	Heterostegina Marginulina Frio	Olig	Ss	25x	80	Ds	2^{16} 4	Vicksburg	4,471
51	Mio Mid. Olig U. Saline Bayou	Mio Olig Eoc	SH	Por	44	Ds	12	U. Saline Bayou	7,386
52	Mio Marginulina-Frio	Mio Olig	SH	Por	29	D	3^{16} 13	Vicksburg	7,096
53	Frio	Olig	SH Ss	Por	90x	Ds	17	Frio	7,471 (Abd. in Salt)
54	Plio-Mio Frio	Pli-Mio Olig	SH S	Por	26x	D	7	Vicksburg	6,988
55	Cockfield	Eoc	Ss	Por	10	MF	1^{16}, x, 11	Cockfield	1,320
56	Gas: Fleming Oil: Frio	Mio Olig	SH SH	Por	7 16	D	9^{16}, 9^{17} 12	Frio	6,012
57	Fleming	Mio	SH	Por	5	Ds	10^{16} 13	Olig	6,271
58	Mio Frio Heterostegina	Mio Olig	SH	Por	32	D	6^{16}, 13	Whitsett	5,840
59	Cap rock Marginulina	Pre-Ter Olig	SH	Cav Por	33	Ds	14^{16} 61	Vicksburg	7,375
60	Cockfield	Eoc	Ss SH	Por				Queen City	7,569
61	Cockfield	Eoc	Ss	Por	12	DF	37	Queen City	7,569
62	Cockfield	Eoc	Ss	Por	9	DF	5	Cockfield	4,240

[17] Number of gas wells drilled before oil discovery.

TABLE 1.—(*Continued*)

Line Number	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
63	Cockfield	Eoc	SH	Por	21	D	5	*y* (L. Saline Bayou)	4,595
64	Cockfield	Eoc	SH	Por	13	DF	4^{16}	Weches	6,062
	U. Saline Bayou				23		13		
65	Cockfield	oc	Ss	Por	4	D		Cockfield	
							9^{16}		
66	Cockfield	Eoc	S	Por	7	D	12	*y* (Saline Bayou)	4,503
67	Pliocene, Caddell, U. Saline Bayou	Eoc	Ss	Por	15	DF	8^{16}	U. Saline Bayou	3,423
							12		
68	Gas: Lagarto, Oakville	Pli-Mio	Ss	Por	10	D	7^{16}	Frio	6,479
	Mid. Olig	Olig			16		25		
69	Cockfield	Eoc	Ss	Por	10	D	4	U. Saline Bayou	4,574
70	Gas: Lagarto	Olig	Ss	Por	10	D	27	Frio	7,211
	Oil: Mid. Oligocene								
71	Gas: Catahoula	Mio	S	Por	28	D	18	(*x*) L. Saline Bayou	6,025
	Oil: Frio, U. Saline Bayou	Olig	SH						
		Eoc							
72	Mio	Mio	SH	Por	28	D	1^{16}	Vicksburg	7,648
	Mid. Olig	Olig	Ss				18		
	Frio								
73	Mid-Olig	Olig	Ss	25	84	D	5^{16}	Frio	6,829
	Frio						31		
74	Mio	Olig	Ss	Por	50*x*	Ds	7	U. Saline Bayou	6,743
	Frio								
75	Frio	Olig	SH	Por	60	D	3	Frio	9,457
76	Cockfield	Eoc	Ss	27*x*	61	D	33	L. Saline Bayou	5,993
77	Frio	Olig	S	Por	10	D	6	Vicksburg	7,715
78	Gas: Catahoula;	Mio,	S	Por	G. 5	D	9	Vicksburg	7,023
	Oil: Frio	Olig			O. 16				
79	Mio	Mio,							
	Catahoula	Olig	SH	Por	20	DF	8	Olig	5,748
							2^{16}		
80	Frio	Olig	S	Por	100	D	6	Frio	8,115
							4^{16}, 1^{17}		
81	U. Saline Bayou	Eoc	S	Por	12	D	10	L. Saline Bayou	6,766
82	Catahoula, Heterostegina, Frio	Mio, Olig	Ss	Por	20,26,10	D	16	Frio	6,795
83	Cockfield	Eoc	SH	25*x*	18	DF	27	U. Saline Bayou	5,596
84	Frio	Olig	S	Por	10	D	1	Frio	6,002
85							4^{16}		
86	Cockfield	Eoc	S	25*x*	9	D	18	L. Saline Bayou	7,438
87	Cockfield	Eoc	S	Por	15	D	8	Cockfield	5,533
	Frio	Olig	Ss	Por	6	D	2	Frio	6,003
88							10^{16}		
89	Frio	Olig	Ss	Por	20	D	11	U. Saline Bayou	4,824
90	Cockfield	Olig	Ss	Por	8	D	3	L. Saline Bayou	8,734
	Catahoula, Frio	Olig	S	Por	8	D	6	Vicksburg	5,012
91			S						
92	Frio	Olig	SH	Por	21	D	1	Frio	8,070
93	Cockfield	Eoc	S	Por	18	D	5	Cockfield	7,695
	Frio	Olig	Ss	Por	10	D		Frio	5,990
94	Reklaw, Carrizo, Wilcox	Eoc	Ss	Por	13	DF	10	Wilcox	3,870
95	Frio	Olig	S	Por	10	D	1^{16}, 6	Vicksburg	8,067
96	McElroy	Eoc	S	Por	7	D		L. Saline Bayou	5,917
97	Frio	Olig	S	Por	22	D		Frio	8,651
							7^{16}		
98	Heterostegina	Olig	S	Por	10	D	7	Heterostegina	6,158
99	Frio	Olig	Ss	Por	7	D	1	Frio	7,245
100	Cockfield	Eoc	Ss	Por	9	D	5^{16}, 7	U. Saline Bayou	6,275
101	Frio	Olig	Ss	Por	13	D		Frio	7,033
102	Frio	Olig	SH	Por	8	D	2	Frio	6,005
103	Marginulina-Frio	Olig	SH	Por	21	D	1^{16} 1	Frio	7,118
104							4,663		

TABLE. 2.—*Summary of Drilling Operations in Texas Gulf Coast*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to January 1, 1935												Completed during 1934										Drilling or In-complete at End of 1934	
	Dry and/or Near-dry Holes											Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes									Productive Wells (For Details See Table 1)		
	Total Depths, Ft.										Total²		Total, Depths, Ft.								Total			
	Less than 1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000	8,000–9,000	9,000–10,000			Less than 1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000			Within Fields	Exploratory
Aransas		2	2			2	1				7								1		1			
Austin	7	6	8	16	10	6	1	1			55	224			1	1	3	2	1		8	17	4	
Bee	8	7	6	19	30	10	6				86	183			1	1	4	2	2		10	65	9	3
Brazoria	25	39	22	35	17	7	10	4			158	439		1			1		4	1	7	49	16	2
Brazos	22	19	6	3	1						51			1							1			3
Burleson	14	19	19	7	1		1				61			1	1				1		3			1
Calhoun			1		1	1	6				9	1							5		5	1		
Chambers	7	22	5	4	2	4	3	1		1	49	367							1	1	2	35	12	2
Colorado	18	28	5	3	7	5	1				67	2						1			1			1
Dewitt	6	3	6	10	8	2	1				36					1	2	1			4			1
Fayette	14	9	15	8	4						50				2	1	1				4			
Fort Bend	53	47	12	19	14	5	10	2	1		163	502	3		1				5	1	10	36	8	1
Galveston	1	13		4	3		1	1			23	67		1					1		2	9	5	1
Goliad	14	14	6	11	24	4	1				74	3			1		2				3			1
Grimes	6	8	14	24	4	2	1				59		3		2	4			1		10			4
Hardin	5	20	8	7	2	1	3	1			47	2,499	1					1	2		4	17	7	
Harris	23	77	38	42	20	15	24	1			240	2,875	1	2	2		1	1	9		16	138	17	6
Houston[1] (Kittrell)												4										4		
Jackson	1	3	6	11	3	1	7				32	13						1	3		4	2		
Jasper	12	23	2	4	4	1	2				48	8						1			1			
Jefferson	16	37	32	29	13	9	7	4			147	1,359		2		1	1	1			5		2	2
Jim Wells	3	2	10	9	6	1	3				34	4				2	1				3	3	2	1
Kleberg	11			3	2						16	18				1					1			1
Lavaca	26	7	1	2	5						41													2
Liberty	6	23	26	23	11	11	6	2		1	109	1,084						3	3	2	8	69	11	3
Live Oak	14	43	22	11	10	3	1				104	33	3	13	2	1	1		1		21	6	1	5
Madison	5	6	6				2				19				1				2		3			1
Matagorda	10	10	10	23	9	7	5				74	132						2	2		4	7	3	1
Montgomery	15	38	5	16	19	23	1				117	844					3	4	1		8	159	8	2
Newton	4	22	3		2	1		1			33							1			1			
Nueces			1	11	3	10	6				31	97						5	4		9	20	2	
Orange	5	16	3	13	5	1	4				47	328	1		1			1			3	5	5	
Polk	2	9	5	6	11	5					38	37		1			1	1			3	23	5	2
Refugio	1		2	7	4	1	8	1			24	586					1		4	1	6	131	6	
San Jacinto	2	6	1	1	10	3					23						4	1			5			
San Patricio	3	1	14	15	9	6	10				58	45			1				9		10	6	6	
Trinity		10	7	2	2						21				1						1			2
Tyler	1	12	5	4	3	4	1				30					1	1				2			
Victoria	1	4	7	8	5	4	5				34	26			1	2	1	1	2		7	15	5	
Walker	12	16	6	13	1	1					49				1	1	1	1			4			1
Waller	9	15	3	11	5	3	1				47	1				1			1		2	1	2	2
Washington	20	11	12	16	1	1					62	45										7	1	
Wharton	11	14	3	5	2	3	7		1		46	148	1	1					2		4	10	7	
Total	413	661	365	455	293	163	146	19	2	2	2,519[2]	11,974	13	23	19	18	29	31	67	6	206	835	144	51

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[1] Only the productive wells in the Kittrell field were counted here.

[2] Does not list 4663 dry or near-dry holes drilled in fields.

owing to the Oil Code, in spite of the fact that distress or "hot" oil from East Texas was a disturbing factor.

In the tables prepared in this year's review, many data have been omitted because it has been found that very little dependence can be placed on the information available on many of the older salt domes. The peculiar conditions associated with some of the salt-dome fields also make conclusions drawn from some of the data inconsistent and susceptible to erroneous interpretation.

NEW OIL FIELDS FOUND IN 1934

Hastings.—Stanolind Oil and Gas Co., a recent newcomer to the Coast, found a new field in northern Brazoria county. A favorable reflection seismograph picture led to this discovery. Twenty-two feet of gas sand was encountered at 5945 ft., or 215 ft. in the Marginulina zone. Ten feet of oil sand, topped at 5980 ft., yielded 5½ bbl. of 38° A.P.I. per hour through small chokes without salt water. Later, because of imperfect gas shutoff, the well was killed, drilled deeper to 6003 ft., and found an additional 10 ft. of sand. The Frio formation is at least 700 ft. above normal. The area is controlled by the Stanolind company.

Dickinson.—An important discovery in 1934 was Dickinson, situated on the mainland 15 miles from Galveston. Attention was shifted there when Humble Oil & Refining Co. No. 1 Maco Stewart blew out and caught fire from Frio sands topped at 7789 ft. The second test, Humble Oil & Refining Co. No. 1-B Maco Stewart, 2500 ft. north of west, was completed after setting 49 ft. 5 in. of screen at 8025 ft. The top of the sand was found at 7998 ft. The well initially produced 33 bbl. of 37.6° A.P.I. oil through small chokes, and three days later began flowing steadily 115 bbl. of oil per day. The third test, which showed the slope of the fold, was Pure Oil Co. No. 1 Shelor, 2200 ft. north of the blowout. The Frio sand was found at 7937 ft., 91 ft. of screen was set at 8016 ft., and the well completed in November, initially for a production of 4,000,000 cu. ft. of gas and 120 bbl. of 58° A.P.I. distillate daily through one 13⁄64-in. choke. These wells, on the northwest slope of the structure, show an oil zone of 51 ft. oil interval and 227 ft. of gas interval. The Pure Oil Co. discovered this structure three years ago with reflection shooting.

Kittrell.—The Kittrell discovery marks the second oil field producing from the Lower Claiborne formations in the Coast. The discovery well, Boone Bros., No. 1 Trinity State Bank, topped the Reklaw sand at 2027 ft. and 21 ft. 4 in. of screen was set at 2036 ft. in September. The well flowed initially 20 bbl. per hour of 24.9° A.P.I. oil through a ⅝-in. choke, but some water appeared within a few days. Producers were later developed in the underlying Carrizo from 1949 to 1989 ft., and in Wilcox sands from 1972 to 2012 ft. Showings were found in the Crockett at 1070 ft., the Sparta at 1347 ft. and the Queen City at 1582 ft. The three oil sands seem to have common gas-oil and water levels. The gas-oil contact is close to 1660 ft. subsea, and the water level near 1740 ft. subsea. The oil interval seems to include over 50 per cent sand. A maximum at 100 ft. of gas sand may occur here.

An inlying outcrop of Caddell formation led to the drilling. Nine dry holes drilled near the discovery well outlined the productive area on all sides except to the northwest. The productive area will be very small. The deepest test was abandoned 1086 ft. below the top of the Wilcox formation at 3870 ft. This discovery has impelled 12 wildcatters in the search for other structures along the so-called "Kittrell trend."

Vanderbilt.—The discovery well, Encino Gas Co. No. 1 Toney, a mile southeast of Vanderbilt, was completed in May in a sand 279 ft. in the Frio formation, 60 ft. of screen having been set at 5282 ft. The first 5 hr. yielded 125 bbl. fluid through a ¼-in. choke, and later 500 bbl. of 32.2° A.P.I. pipe line oil daily. Traces of salt water were suggested. A northwest offset to the discovery well, Encino Gas Co. No. 1 Simmons-Siedel, found water in these sands and water sands from 5500 to 5581, 5673 and 5912 ft. Three dry holes have been drilled north and northwest from the lone oil well.

Eureka.—Bunte et al. No. 1 Lackner, northwest of the Houston city limits, was completed at 7695 ft. in sand 232 ft. below the top of the Cockfield. Eighteen feet of screen was set, although 33 ft. of sand was penetrated. It produced 1,000,000 cu. ft. of gas daily, and one barrel of 54.6° A.P.I. distillate per hour.

Bay City.—The Bay City field, or Van Vleck, is 5 miles north of Bay City, Matagorda County, Texas. Attention was directed to the area by reflection exploration, and the first well was completed in March for an initial production of 35 bbl. of 56° A.P.I. distillate and 5,000,000 cu. ft. of gas through a ⅛-in. choke, in the Marginulina-Frio sand between 7001 and 7043 ft. It was plugged back to test these sands after showing salt water in two deeper sands from 7172 to 7178 ft., and from 7113 to 7115 ft. It was recompleted in April for 198 bbl. of 50.88 A.P.I. gravity oil through small tubing and casing chokes. A second well was completed in this zone later, in October, for an initial production of 287 bbl. of 40° A.P.I. oil for the first 22 hr. on a ⅜-in. choke; 14 ft. of screen was set from 7048 to 7060 ft. Practically the entire area is controlled by the Skelly Oil Company.

Old Ocean.—Harrison & Abercrombie No. 1 Brazos River Land & Development Co. was completed in upper Frio sand encountered between 8629 and 8651 ft., or 218 ft. below the top of the Frio formation, as a distillate well. The first 24-hr. gage showed 512 bbl. of fluid, of which 22 per cent was salt water, through a 3/16-in. choke. The gravity of the distillate was 67.4° A.P.I. The top of the Discorbis zone is about 200 ft.

above normal and the interval between the top of the Discorbis to the top of the Frio, over 1900 ft., and is one of the thickest known on the coast. This well is the deepest producing on the Texas Gulf Coast. Old Ocean was first prospected in 1923 when Miocene showings were found by the Transcontinental Oil Co. at 4008 ft. The present discovery was the result of reflection seismograph work.

Splendora.—In early 1934 attention was centered upon Splendora, 8 miles east of Conroe, where a very active lease play preceded the completion of Steen Drilling Co. No. 1. Texas Long Leaf Lumber Co., in June. A drill-stem test made several weeks earlier, showed distillate and gas. During the first 12 hr., the well averaged 22½ bbl. per hour of 64.6° A.P.I. distillate with a large flow of gas, through a small choke. The producing sand is 61 ft. below the top of the Cockfield. The well was drilled into salt water at a total depth of 6041 ft., then plugged back to 5841 ft. and completed. In July it began to show salt water through ¼-in. choke and was then killed. In addition to the discovery well, two adjacent dry holes drilled to the Cockfield formation found good sand.

West Tuleta.—In June, Dirks Bros. No. 1 Skinner & Harris, situated about three miles west from the Tuleta pool, was completed in sand found from 3950 to 3974 ft., topped 18 ft. below the top of the Cockfield. This sand is productive also in the Tuleta pool. The first 12 hr. the well gaged 48 bbl. 47.3° A.P.I. oil through ⅜-in. choke. The best well, Heyser-Heard & Walton No. 1 Rapp, was completed for an initial production of 440 bbl. per day through a ½-in. choke, in 7 ft. of Cockfield sand from 3906 to 3913 ft. The boundary of the pool is established on the north by a fault and on the east and southeast by the salt-water table, while the west and southwest boundary is unprospected. Twenty oil wells have been completed in this pool. In December, a test 3300 ft. southwest of the nearest oil well was completed in an oil sand topped at 3949 feet.

Tom O'Connor.—In June, Quintana-Humble No. A-1 Tom O'Connor, at 5575 ft., was completed with 20 ft. of screen, flowing 21 bbl. per hour on ⅜-in. choke. By August, the well had declined to 350 bbl. per day fluid, 50 per cent being salt water, through a 5⁄16-in. choke. After reworking in 11 ft. of sand from 5912 to 5923 ft., it yielded 147 bbl. per day of 35.6° A.P.I. oil on a 3⁄16-in. choke. These two sands occur 1000 and 1400 ft. below the top of the Frio formation. Three oil wells have been completed in the 5900-ft. sand. The few wells completed give little hint of the structural relations.

Caesar.—The Caesar area, in northern Bee County 6-½ miles northwest from Pettus, first attracted attention in 1928, when a shallow Pliocene gas area 380 ft. deep was discovered. The general locality had sporadic drilling, and in May, 1934, a gas sand was discovered by the Caesar Oil Co. No. 1 C. E. Pullin. It was completed for 20,000,000 cu.

ft. of dry gas on a ¼-in. choke in 18 ft. of basal Caddell sand found from 3016 to 3034 ft. In June, Houston Oil Co. No. 1 Carson, a west offset, developed a deeper sand, of Upper Saline Bayou age, which showed 1160-lb. tubing working pressure at 3280 ft. and 238 ft. below the top of the Cockfield formation. Attention was attracted again to this area in October, when the Luling Oil & Gas Co. completed No. 1-C Ruhman for 140 bbl. on two 3⁄16-in. chokes in the upper, or Caddell sand, at 3062 ft. At the end of 1934, the area had one shallow gas well at 380 ft.; three gas wells from 3025 to 3050 ft.; one Upper Saline Bayou formation gas well at 3280 ft.; two Caddell formation oil wells at 3060 ft.; and three dry holes, two of which penetrated the Upper Saline Bayou and one the Cockfield formation.

Brookshire.—In September a super-cap area was developed on the Brookshire dome when Seaport No. 1 Vaughn was completed in Frio sandy shale, between 2956 and 2966 ft., or 386 ft. below the top of the Frio formation and about 230 ft. above cap rock. Initially pumping, it produced 2½ bbl. of 22.2° A.P.I. oil per hour for 3 or 4 hr. with very little gas. The well was drilled 10 ft. deeper to 2978 ft., and it flowed around the drill stem, with no gas, for approximately 10 hr.; and was finally completed Oct. 23, flowing 8 bbl. per hour through a ¼-in. choke, 50 per cent oil and 50 per cent fresh water, and 100 lb. working pressure. Two deep flank tests, as well as nine wells in the super-cap area, have failed previously to discover important oil and gas deposits.

Northwest Tuleta.—During December, Dirks Bros. No. 1 J. E. Roth, 1½ mile northwest of the northwest edge of the West Tuleta pool, promised to uncover a new Pettus-sand oil pool. This well was finished for 306 bbl. of oil in sand between 3880 and 3884 feet.

Angelita.—Attention was drawn to this area, 10 miles southwest of Sinton in San Patricio County, in March, when Atkins & O'Neil No. 1 James Welder was completed in a sand and shale-oil section between 5374 and 5383 ft., or 1100 ft. below the top of the Frio formation. Initially, the well flowed 50 bbl. of 35° A.P.I. pipe line oil, through a small choke. The relatively few tests are still insufficient to suggest the extent or thickness of the sands.

Dinero.—Dinero lies 3 miles northwest of Mount Lucas gas field. In August, Lion Oil & Refining Co. No. 1 McNeil was completed for 204 bbl. of 44.5° A.P.I., on a small choke in 6 ft. of McElroy sand at 4376 ft. This test is the first commercial oil produced from the McElroy formation southwest of the Raccoon Bend field in Austin County, Texas. A new deep horizon was found during November when Lion Oil Co. No. 2 McNeil blew out at 5917 ft. in Lower Saline Bayou formation sands.

Sinton.—In May, Plymouth Oil Co. No. 1-A E. H. Welder, 2 miles north of Sinton, was completed for 5 bbl. per hour on a ⅜-in. choke of 50° A.P.I. oil. Nine feet of sand from 5415 to 5426 ft., and 8 ft. of broken sand and shale from 5426 to 5434 ft. produced 955 ft. below the top of the Frio. This well had been drilled to 6602 ft., was plugged back, sidetracked, and redrilled to test these sands, which were intimated by an electrical survey. A 12-hr. gage showed 48 bbl. of 50° A.P.I. oil through a ⅜-in. choke and an estimated volume of 10,000,000 to 12,000,000 cu. ft. of gas. A second sand was found in the middle of the Frio formation from 5884 to 5890 ft. in Heep Oil Co. No. 4 Welder. This sand showed 25 bbl. of 33° A.P.I. oil and 75 bbl. of salt water, through perforated casing, after reaching the depth of 7245 ft. Two oil wells and one gas well have been drilled in the area. Sands that had not been reported by the driller were recognized by an electrical survey and were developed into oil or gas production.

Port Lavaca.—In Calhoun County, during the latter part of November, a gas and distillate sand was discovered in Steen Drilling Co. No. 1 Stanzel, 2 miles northwest of Port Lavaca. This sand was found in the Heterostegina zone from 6145 to 6158 ft. and produced initially 3 bbl. per hour of 60.6° A.P.I. distillate through a 12⁄64-in. choke.

Fordtran.—The Fordtran area is in the northern corner of Victoria County, midway between Victoria and Hallettsville. The first test, The Texas Co. No. 1 Midgett, was drilled to the Crockett at a total depth of 5790 ft., with little result. The well was plugged back and uppermost Frio sands found from 2823 to 2840 ft. furnished 1,560,000 cu. ft. of dry gas through a ¼-in. choke. Two wells later drilled in this area developed salt water in these and other sands.

New Horizons Found in Settled Pools

The year 1934 witnessed a continuance of exploitation in many of the old oil fields, but no flashy rejuvenations were developed comparable with the Hull revival of 1933, which quickly faded out because of close drilling.

Raccoon Bend.—Production in the Conroe sand at Raccoon Bend was discovered during April in Humble Oil & Refining Co. No. 1 Zeiske at a depth of 4047 ft., or 205 ft. below the top of the Cockfield formation. Up to the close of the year, 14 oil wells, 1 gas well and 15 dry holes had been drilled to the Conroe sand. One of the dry holes in the center of the Cockfield oil area, in the graben, found the sand faulted down below the water level. The water level for the Conroe sand is minus 3990 ft. and the highest well found the top of the Conroe sand at minus 3804 feet.

Raisin.—Raisin, or Coletto Creek, was discovered during the latter part of 1933, and the continuance of development during the past year brought about the discovery of three new oil sands in the Catahoula formation. The first sand occurs at 2209 ft., the second at 2332, and the third from 2800 to 2875 ft. In the shallowest sand five wells were completed, four of which very soon showed water. The discovery well in this sand, Nu-Tex, No. 1 Zimmer, was completed in August, and produced initially 30 bbl. per day on a ¼-in. choke. The 2332-ft. sand was discovered in September, by the same company's No. 2 Zimmer, which was completed for an initial production of 150 bbl. per day through a ¼-in. choke. The oil was 24.6° A.P.I. at 97° temperature. The 2800 ft. horizon was discovered in August by the American Liberty Co. No. 1 Pribyl, in a sand from 2796 to 2801 ft. Initial production was 400 bbl. per day through a 5⁄16-in. choke, 80 per cent of which was oil. The development of this district during the year was restricted to prospecting the shallow horizons.

Hankamer.—Hankamer was developed on the southeast and southwest sides. During March, Sterling Oil Co. No. 1 Crow, about ¾ mile southeast of production, was completed in Miocene sands at 4570 ft. with 22 ft. of screen and started making dry gas. Three days later, the well flowed oil at the rate of 200 bbl., 26° A.P.I. gravity, daily, through 5⁄16-in. choke, but soon died and was later abandoned. In this vicinity, Gulf No. 3 Crow and Jacobs, during December, was completed with 22 ft. of screen and flowed 627 bbl. of 28.4° A.P.I. gravity oil on ¼-in. choke daily. This is the first Marginulina-Frio producer in the area, though several wells had tested that horizon. On the west side of the field, in October the Cretaceous Oil Co. completed a well in the Miocene formation at 2615 ft. which had an initial production of 252 bbl. daily on a small choke. This was an 1100-ft. extension of the 2600 to 2700-ft. sand.

Port Neches.—The Frio sand topped at 5995 ft. was noted at Port Neches during March, in The Texas Co. No. 2-B Polk. In August, after plugging back from the total depth of 6708 ft., 43 ft. of screen was set in the sidetracked hole at 5918 ft. and the well completed through two small chokes, making 14 bbl. of 35.6° A.P.I. oil per hour. It held up well, having gaged 1074 bbl. per day, on Sept. 3.

Rock salt was first penetrated at Port Neches in The Texas Co. No. 2 Orange National Bank in 1934, at 7250 ft., which is the greatest depth for salt to be found in a deep-seated salt dome.

Mykawa.—West Production Co. No. 1 Diamond, 3500 ft. northeast of the old oil area, found a new oil sand in the Heterostegina zone at a depth of 4444 ft., and was completed as a 90-bbl. pumper. Four additional oil wells were drilled, of which three were completed in the Frio formation and one was ruined in the Miocene when it blew out and cratered.

Piedras Pintas.—The old Piedras Pintas salt dome, which had been prospected as deep as the Claiborne formation, produced in McElroy sands at 3472 ft. The well, Graham & Texana Royalty Co. No. 1 Parr, is on the northeast flank of the salt dome where Claiborne oil had been found in 1925 in Humble Oil & Refining No. 4 Walsh. The Parr well was completed flowing 25 bbl. per hour of 52° A.P.I. oil, through a ⅛-in. choke. Two months later a second well was completed in that sand, for an initial production of 22 bbl. per hour through 2-in. open tubing.

Ariola.—At Ariola, two Miocene-Pliocene sands were discovered during 1934. The deepest sand was found about 1000 ft. above the salt, in Republic-Houston No. 10 Ariola Fee at 3579 ft. The well flowed 7 bbl. hourly of 20.6° A.P.I. oil through ¼-in. choke and a few days later went dead. This well also had showings around 3000 ft., which had been developed during September in No. 3-X Ariola Fee. In that test the top of the sand was found at 3077 ft.; 20 ft. 5 in. of screen was set at 3086 ft. and the well came in through a 5⁄16-in. choke for 10 bbl. of 24.9° A.P.I. oil per hour. Within a month this well went dead and was drilled 5 ft. deeper, to 3091 ft., but was abandoned in salt water.

McFaddin.—A deep sand in the Frio formation was developed during November in the Texas Co. No. 2 A. M. McFaddin. This test found a sand at 6178 to 6187 ft. and flowed 300 bbl. of 47.1° A.P.I. oil on three 1⁄16-in. chokes, in the basal part of the Frio formation.

Batson.—On the south flank of the Batson salt dome a commercial oil well in the Upper Saline Bayou formation was finished in November. This well, Deering & Batson Oil Co. No. 1 Hooks, the third drilled in that vicinity, was located slightly farther out on a lower slope of the dome. It came in flowing dry gas and wash water through a 3⁄16-in. choke on Nov. 4, and was soon making 39.2° A.P.I. oil at the rate of 75 bbl. per day through a ⅛-in. choke. The sands in this well at 4954 ft. lie 53 ft. below the top of the Upper Saline Bayou formation.

Saratoga.—A unique development at Saratoga was the discovery of oil within deeper cap rock on the east flank. This is the deepest cap-rock oil that has yet been found; and is the first here, the shallow cap rock having hot salt and sulfur water at 1400 ft. This test, Hines Bros. No. 1 Caswell, went from Upper Saline Bayou formation into cap rock at 3286 ft. In August, porous cap rock showing oil was encountered at 3320 ft. Casing was set at 3299 ft. and 26 ft. of screen was set at 3320 ft., but the well failed to produce. Later the well pumped, and flowed by heads, 4 bbl. of oil per hour. The gravity of this oil is more suggestive of Cockfield or Saline Bayou than low-gravity sulfur-bearing cap-rock petroleum.

West Columbia.—A new sand was discovered on the southeast flank of West Columbia, in upper part of the Vicksburg formation. Sterling et al. No. 2 Hogg was completed during November for an initial production of 385 bbl. of 48° A.P.I. oil through ¼-in. choke, after the casing had been perforated between 5138 and 5150 ft. Four days later the well had dropped to 5 bbl. per hour and was making 2 per cent basic sediment and water.

EXTENSIONS OF OLD HORIZONS

Manvel.—At the beginning of 1934, the north Miocene sand slope of Manvel had been fairly well defined by drilling, and the limits of the Oligocene structure had been extended approximately ⅘ mile south with the completion, in January, of The Texas Co. No. 6-B Belcher. This well made 37 bbl. per hour of 26.1° A.P.I. gravity oil on a ⅜-in. choke in 14 ft. of Marginulia-Frio sand from 5109 to 5123 ft.

Two producing zones have been developed at Manvel. The upper zone is found at depths ranging from 3850 to 4000 ft., depending upon the relative position of the well upon the northern slope of the fold, and consists of 25 to 50 ft. of lower Miocene sand and sandy shale, 75 per cent of which is sand. The best wells in this zone make 750 bbl. per day of 25° A.P.I. gravity oil through small chokes. The lower zone, of Marginulina-Frio age, is found at various depths below 5000 ft., depending upon the faults, and is segregated into three areas having three oil-water levels. The best Marginulina-Frio wells produce initially 900 bbl. of 27° A.P.I. oil daily on small chokes. During 1934, the productive interval, sand thickness, size and extent of structure, showed Manvel to be a first class oil reservoir.

Tom Ball.—At Tom Ball, in 1934, an important extension was the completion of Humble Oil & Refining Co. No. 1 M. H. Gossett, on the southeast side of the Tom Ball field. This well extended the productive strip a mile northeast. Along the main fault, which crosses the Goodrich and Hooper surveys, the Schultz sand was found within the oil interval. At the end of 1934, drilling had shown five major faults. North and northwest of the northernmost fault, the Kobs, or first sand, does not exist, the section consisting of sandy shales; consequently, a large area is eliminated from production.

Louise.—The main oil zone developed during 1934 was the 5100-ft. sand, averaging 7 ft. in thickness. It occurs in the very top of the Frio formation. During the past year, five of the eleven completions were made in this zone, and the best well was finished for 196 bbl. of 25° A.P.I. oil hourly on a ⅜-in. choke in sand from 5138 to 5147 ft. Oil horizons also occur at 6460 and 7143 ft., in the middle and basal parts of the Frio formation, two wells having been completed in the former and one in the latter zone. These sands have distillate. Still another sand, from 5966 to 5976 ft., produced initially 234 bbl. of 36.6° A.P.I. oil with 1.5 per cent basic sediment and water.

Cleveland.—Cleveland was found during December, 1933, when Gulf Production Co. No. 1-C Kirby was brought in from 8 ft. of upper Cockfield sand. The field has been limited on all sides except the east and west by deep dry holes, and the oil sands are poorly developed. The main Conroe sand horizon, as well as the upper Cockfield sand, is productive, but most of the five oil wells make some salt water.

Goose Creek.—Goose Creek experienced another revival, initiated by the completion in November, 1933, of Gulf Production Co. No. A-17 Tabb, through a 5⁄16-in. choke for 1080 bbl. of 31.1° A.P.I. oil in sand from 4486 to 4501 ft., or 209 ft. below the top of the Marginulina zone. Four months later the well was producing 207 bbl. daily through a 1⁄4-in. choke. This well is on the east side of the structure within the Miocene-Pliocene productive area. The result of the 1934 development has been 22 wells, of which 12 were completed for initial production ranging from 10 to 1080 bbl. daily on small chokes. Eight of these were Frio horizon dry holes, and two Miocene failures.

Sour Lake.—The year 1934 witnessed a continuance of deep east-flank Cockfield development. It was explored 3000 ft. farther east and 2500 ft. deeper than previous easternmost development. J. W. Parr No. 1 Bernard found the Cockfield formation at 6935 ft. and had heavy showings of gas. Seven-inch casing was set at 6880 ft. and 22 ft. 3 in. of screen was set at 6952 ft. Thirty days later screen was pulled, the well drilled deeper, and 110 ft. of 3-in. screen was reset at 7061 ft. Afterwards, the well blew the swab and 200 ft. of line out of the hole, and flowed for 3 hr. through 3⁄8-in. and 1⁄2-in. tubing chokes an average of 10 bbl. of 31.7° A.P.I. oil per hour, 45 per cent oil and 55 per cent wash water.

Livingston (North Extension).—During March, a test 3500 ft. northwest of the Livingston field was completed as a gas distillate well in the Cockfield formation. This test, Gist et al. No. 1 G. P. Reed, had set 46 ft. of screen at the total depth of 4242 ft. and the initial production was estimated at 2,000,000 cu. ft. of gas and 35 to 45 bbl. of distillate per day through a 1⁄2-in. choke. That completion led to further prospecting. The first successful oil completion, in July, J. Z. Werby No. 1 Falling, set 20 ft. of screen at 4337 ft. and the initial production was 67 bbl. of 44.8° A.P.I. oil through a 11⁄64-in. choke.

Pledger.—Humble Oil & Refining Co. No. 1 McFarland found the highest point on this Oligocene structure reached to date. In this well, 6000 ft. southeast of the nearest gas well, the top of the gas sand is 102 ft. higher than found heretofore. More than 200 ft. of sand occurred wholly within the gas zone. Below the gas-bearing sands a 7-ft. shale break separated the underlying thin salt-water sands. Top of the gas sand was found at 6557 ft. and the well was deliberately drilled into salt water, plugged back, and completed for 13 million cubic feet of gas daily through a small choke.

Boling.—The northeast flank of Boling salt dome was prospected with rather indifferent results during the year. One well, Seiber et al. No. 1 J. R. Farmer, 1700 ft. northeast from the nearest oil, was completed in a Frio sand from 4396 to 4428 ft. for an initial production of 24 bbl. per hour, 38 per cent basic sediment and water, through a 3⁄8-in.

choke, gravity 22.2° A.P.I. The well soon died. No. 1 E. C. Farmer, of the same company, slightly south of the first well, found an upper Frio sand at 4418 ft., which carried salt water.

Agua Dulce.—This field was extended south about two miles upon completion of two outpost wells, the first of which was completed in September in Upper Frio sands at 4775 ft. The operators, Texon Royalty No. 1 Walton, made an electrical survey and set casing without making a drill-stem test. Initial production was estimated at 40 bbl. of gasoline per day through ⅜-in. choke. In November, the productive limits were again extended 4500 ft. farther south with the completion of Texon Royalty Co. No. 1 Driscoll, for an initial production of 50 to 60 bbl. of gasoline per day through a ⅜-in. choke, at 4901 feet.

Mount Lucas.—Houston Oil No. 27 Cartwright, in the middle of the old Mount Lucas field, was completed in October for a 147-bbl. well, through 2-in. tubing in basal-most Frio sands at 3500 ft. Thirty-one feet of screen was set in the bottom of the hole.

MISCELLANEOUS DEVELOPMENTS

At Tom Ball, Louise and Greta, development progressed with little or no change in the status of these fields. Hull, Conroe and Thompsons were steadily developed, so that 1934 saw the virtual completion of drilling in these areas. At the close of 1934, the following districts were active, as the following disposition of rigs shows:

Texas	Active Rigs	Texas	Active Rigs	Texas	Active Rigs
Barber's Hill	16	Refugio	8	Conroe	4
Tom Ball	10	Hull	6	Port Neches	4
Manvel	9	Pierce Junction	6	Greta	4

At Ace, Polk County, through December, the lone commercial gas-well completion, Schwab No. 2 Kirby West, had produced 5768 bbl., or a daily average of 48 bbl. of 59.7° A.P.I. gravity oil, with enormous amounts of gas.

Near Katy, on the common corner of Harris, Waller and Fort Bend counties, during December, Stanolind Oil & Gas Co. No. 1 Thorp encountered the Conroe sand at 6370 ft. It encountered showings in many Cockfield and Upper Saline Bayou sands. At 553 ft. below the top of the Cockfield this test had penetrated over 100 ft. of gas sand. The first gas showing was at the base of the Caddell formation and continued through the Cockfield to the top of the Upper Saline Bayou.

At Nome, Sun-Shell No. 1 Paggi encountered a showing of oil during October, 1933, at 6028 ft., which did not respond to swabbing. The well was drilled deeper and finally abandoned at 7265 ft. In December, 1933, the second well, Sun-Shell No. 1 Hugh Long, was started and is now drilling below 8643 ft. Last August this test encountered sand in the Vicksburg, showing oil at 8585 ft., and had enough gas pressure to attempt to blow out. Later, the drill pipe was stuck and well was sidetracked at 6251 ft. During the latter part of November, the well again encountered the same good showings of oil and gas between 8449 and 8454 feet.

Perhaps one of the most significant technical events of the past year was the killing of the Alexander cratered well at Conroe, by planting a bubble of water in the oil sand around the bottom of the crater conduit through a deviated hole drilled as a joint project with several operators. The surface of the crater ceased rolling after 26,000 bbl. of water had been injected into the deviated hole, Humble Oil & Refining Co. et al. Alexander No. H-1. On Jan. 15, the last oil was flowed from the crater. At that time the water injected into the relief well, and poured into the crater, aggregated 95,924 bbl. The total quantity of oil produced from the crater up to that date was 1,547,343 bbl. The peak of recovery from the crater was 9884 bbl. per day on July 28.

RECENT IMPROVEMENTS IN DRILLING AND EXPLORATION PRACTICES

In the early days of Gulf Coast exploration, intentionally deviated holes had been drilled by means of tilting the rotary table when spudding, and controlling the weight and speed of rotation. More recently several ingenious tools in the form of whipstocks and knucklejoints have been invented for deviating drill holes; and improved well-surveying equipment has made it possible to bottom a drill hole at almost any desired point. Several operators intentionally drilled slant holes to an objective horizon, either to reach productive sands in more favorable positions, to go around salt overhang, or to straighten crooked holes.

Formation testers are universally used in wildcatting to test sands without setting casing. Gun perforators, which are discharged by electrically detonated shells with hardened steel bullets, are used for perforating pipe opposite sands that are to be tested.

During the year the introduction of heavy California-type rotary equipment at Bosco, La., was of great interest. This equipment included superheated boilers, using 350 lb. pressure, and double hoisting equipment. The use of 40-ft. joint drill pipe is becoming more general. Special equipment for reconditioning mud, and extra heavy pumps capable of maintaining 1800-lb. circulating pressures, literally hydraulic through the clastic Coastal sediments.

Considerable experimentation with synthetic muds for the purpose of drilling "heaving shales" of the Vicksburg and Jackson formations has been in progress. Drilling also has been carried on with flush joint casing in a further effort to get through such shale.

The practice of coring and drilling completely through the pay and setting casing on the bottom of the hole and later perforating opposite the oil sands has been tried with success. The use of bottom-hole chokes in an effort to reduce the gas-oil ratios and as an economical means of withdrawing gas from gas wells without an expense of surface set-up became fairly general during the year. In work-over wells, particularly in areas where chemical action has tended to consolidate the producing section, it has been found practical and profitable to perforate the old screen rather than to set a new one. The introduction of a 10-ft. wire-line core barrel has resulted in its general use throughout the coast in coring. The use of electric well-surveying devices, which has gained so much ground in 1934, should greatly increase during this year.

Geophysics

At the close of the past year, 22 reflection seismograph crews were exploring the Texas Coast. Torsion balance exploration eased off, with 15 crews as compared with 19 in 1933. One company maintained two pendulum crews continuously throughout 1934. To that method goes the credit for Cleveland. Two magnetometers and two gravity meters completed the assemblage of geophysical instruments, bringing the total to 43. To the reflection seismograph goes credit for discovery of Hastings, and it was accessory to the torsion balance at Dickinson.

Acknowledgment

The writer is indebted to Messrs. L. P. Teas and L. T. Barrow for valuable criticism, and John V. Boyce, of Humble Oil & Refining Co., for assembling the data and preparing the tables appearing in this report; also to Messrs. George B. Corless and W. T. Doherty, production engineers, of the Humble Oil & Refining Co., for various production data. The assistance and cooperation of a great many Gulf Coast operators is also gratefully acknowledged.

Oil and Gas Development and Production in North Texas for the Year 1934

By H. B. Fuqua* and B. E. Thompson*

The area discussed herein, commonly known as the North Texas district, embraces the following 10 counties: Archer, Baylor, Clay, Cooke, Foard, Hardeman, Knox, Montague, Wichita and Wilbarger. It is underlain by two major structural features. The northernmost portion of the district, including Cooke, Montague, northern Clay, Wichita, Wilbarger, Foard and Hardeman counties, is underlain by the system of buried mountains known as the Red River uplift, which is parallel to and closely related to the Wichita-Amarillo uplift of Oklahoma and the Texas Panhandle. While the presence of a great majority of the numerous oil fields of the area is traceable to this feature, the production in Archer, southwestern Clay and southeastern Baylor counties is due to the influence of what is known as the Cisco Arch (so called because of its influence on Cisco deposition), the axis of which extends in a northwest-southeast direction across Archer County.

It has been impossible for the authors to isolate the statistics for production for each of the many small pools of this district, as such statistics are not kept by the operators except for the district as a whole, therefore Tables 1 and 2 are comparatively short. The number of wells

Table 1.—*Oil and Gas Production in North Texas*

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres: Oil	Area Proved, Acres: Oil and Gas[a]	Area Proved, Acres: Gas	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1934	Total Oil Production, Bbl.: During 1933
1	Petrolia[1], *Clay*	32	500	1,000	4,000	5,500	5,995,054	118,757
2	Worsham, *Clay*	11	100	0	0	100	206,000	0
3	Others, *Clay*		300	0	0	300	140,000±	50,000±
4	All fields, *Wichita*	23	40,100	0	100	40,200	243,690,987	5,709,169
5	All fields, *Wilbarger*	22	8,960	0	0	8,960	52,992,062	2,868,501
6	All fields, *Archer*	22	21,355	0	0	21,355	92,286,408	4,684,375
7	All fields, *Montague*	12	3,330	500	500	4,330	20,144,256	1,519,172
8	Portwood, *Baylor*	10	280	0	0	280	1,145,499	94,621
9	All Fields, *Cooke*	9	2,050	0	0	2,050	8,413,143	563,382
10	Thalia, *Foard*	8	0	100	0	100	200,695	24,839
11	Johnson, *Foard*	2	0	200	400	600	364,947	56,341
12	Total		76,975	1,800	5,000	83,775	325,579,051	15,689,157

[a] Footnotes to column heads and explanation of symbols are on page 249.

[1] For Petrolia field, total gas production was: to end of 1934, 97,939,901 M. cu. ft.; during 1933, 412,782 M. cu. ft.; during 1934, 306,357 M. cu. ft. Gas production data not available for other areas.

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* Gulf Production Co., Fort Worth, Texas.

also has been subject to estimate as many of the shallower holes are not reported.

DEVELOPMENTS DURING 1934

Owing to the depressing influences which carried over from the previous year, development in North Texas continued at a minimum during the year 1934. Some deep drilling was carried on, while several extremely local prolific spots within semiproven areas were found in Wilbarger, Cooke and Archer counties, and extensions to older producing areas were developed in Archer, Montague, Wichita, Wilbarger and Foard counties.

Two deep tests, one in Wilbarger County and one in Archer, were probably the most important developments of the year. The W. B. Hamilton No. 2 Giddings Estate, 2 miles north of Anarene in Archer County, encountered a good showing of oil in a chert conglomerate of probable lower Bend (Pennsylvanian) age from 5154 to 5164 ft. Oil filled up 1100 ft. in the hole and the owners are still attempting to complete a commercial producer. The Phillips Petroleum Co. No. 2 W. T. Waggoner Estate N, 10 miles south and 6 miles east of Vernon in Wilbarger County, was drilled to a depth of 4212 ft., after having encountered a good show of oil and gas at 3870 to 3872 ft., slightly below the top of Ellenburger limestone. This showing, while not of commercial importance, may stimulate additional deeper prospecting in the area. This test was plugged back to the regular producing limestone pay at about 2000 ft. and is included as a producing well in the figures in Table 1.

Of next importance in the district was the intensive drilling campaign carried on in the "Lime" area southwest of Archer City in Archer County.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.		Average Oil Production, Bbl.			Number of Oil and/or Gas Wells							Depth, Ft.	Oil Production Methods at End of 1934	
							During 1934	At End of 1934						Number of Wells	
	During 1934	Daily Average during Nov. 1934	Per Acre to End of 1934^b	Per Acre-foot to End of 1934	Per Well Daily during Nov. 1934	Completed to End of 1934	Completed	Producing Oil Only	Producing Oil and Gas^c	Producing Gas only	Total Producing		To Top of Productive Zone	Flowing	Pumping
1	158,054	327	4,000	400±	1	546	9	414	*x*	50	464		1,500	0	414
2	0	0	2,060	52±	0	4	0	0	0	0	0		3,500		
3	40,000±	150±	470	94±	5	50±	0	29	*x*	0	29		1,000	0	29
4	5,558,987	14,953	6,070	303±	2	10,701	88	6,894	0	0	6,894		1,500	0	6,894
5	3,050,062	8,235	5,910	295±	6	1,805	63	1,319	*x*	0	1,319		1,700	0	1,319
6	7,013,408	16,786	4,335	434±	4	5,723	672	3,837	0	0	3,837		1,000	0	3,837
7	1,619,256	4,405	5,250	263±	6	749	43	711	*x*	20	731		1,000	0	711
8	109,499	241	4,100	410±	6	59	3	42	0	0	42		1,400	0	42
9	578,143	1,554	4,110	411±	6	339	10	277	*x*	0	277		1,200	0	277
10	25,036	72	2,000	91±	10	12	1	7	*x*	4	11		2,000	0	7
11	308,606	672	1,825	61±	168	5	3	0	4	0	4		3,800	4	0
12	18,461,051	47,395				19,993	892	13,530	4	74	13,608			4	13,530

This situation was discussed at some length last year[1]. During the year 1934, about 600 wells were completed in the area and drilling continues at a lively pace. The wells, after treatment with hydrochloric acid solution, respond with large initial yields, which decline rapidly, and the ultimate per acre recovery is not expected to be large. However, the wells are relatively inexpensive and a nice profit will be shown by many of the operators.

The Johnson pool, opened during late 1933 by The Texas Company in Southwestern Foard County, has proved, by the addition of three more large wells, to be of commercial importance, although present data still suggest that it will be of limited extent. That company's well No. 7, now drilling, is across the line to the northwest in Cottle County, about ½ mile from the nearest producer.

ACID TREATMENT

In addition to activities in the "Lime" area of southwestern Archer County, the treatment of lime and sandy lime pays with hydrochloric acid solution has been practiced rather extensively in North Texas. Very satisfactory results have been obtained in Wilbarger County and fair results in Cooke County; while in Montague County, near the western limits of the Nocona producing district, a saturated lime at the 1700-ft. level that failed to produce naturally has yielded satisfactory results after acid treatment. In Wichita County, in the South Electra district, good results have been obtained by treating limestone pays found

TABLE 1.—(*Continued*)

Line Number	Character of Oil Approx. Average during 1934					Producing Rock					Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Gravity A.P.I. at 60° F.			Sulfur, Per Cent	Base[f]	Name	Age[g]	Character[h]	Net Thickness Average, Ft.	Structure[i]		Name	Depth of Hole, Ft.
	Maximum	Minimum	Weighted Average										
1	y	y	36.0	0.15	P	Numerous	Per, Pen	S	10±	A	409	Cam-Ord	4,289
2	y	y	43.4	0.47	P	Worsham pay	Pen	Ls	40±	D	6	Strawn (Pen)	3,950
3	y	y	36.5	0.25	P	Numerous	Pen	S	5±	MC	334	Strawn (Pen)	3,985
4	41.8	36.1	39.0	0.30	P	Numerous	Per, Pen	S, L	20±	A, M	7,802	Pre-Cam	3,502
5	38.5	35.5	37.0	0.65	P	Numerous	Per, Pen	S, L	20±	A, D	885	Pre-Cam	3,007
6	40.2	36.8	38.5	0.38	P	Numerous	Pen	S, L	10±	ML	5,723	Cam-Ord	5,750
7	34.0	24.1	29.0	0.90	P	Numerous	Pen	S, L	20±	A, D	286	Pre-Cam	2,915
8	37.0	37.0	37.0	0.38	P	Swastika sand	Pen	S	10±	ML	59	Strawn (Pen)	4,265
9	41.0	23.5	35.0	0.65	P	Several	Pen, Ord	S, L	10±	A, D	359	Pre-Cam	3,790
10	y	y	39.0	0.20	P	Thalia sand	Pen	S, L	22±	D	12	Pre-Cam	2,550
11	45.0	40.8	43.0	0.30	P	Johnson lime	Pen	L, S	30±	D	5	Pre-Cam	5,003
12											15,880		

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[1] H. B. Fuqua and B. E. Thompson: Oil and Gas Development in North Texas for the Year 1933. *Trans.* A.I.M.E. (1934) **107**, 322.

between the 1800 and 2200-ft. levels; while the deep pay in the K.M.A. district to the south (3600-ft. level) responds readily to treatment.

TABLE 2.—*Summary of Drilling Operations in North Texas*
(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1935								Completed during 1934						Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes							Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes					Productive Wells (For Details, See Table 1)		
	Total Depths, Ft.								Total Depths, Ft.							
	0–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	Total		0–1000	1000–2000	2000–3000	3000–4000	Total		Within Fields	Exploratory
Archer	1,068±	4,238	187	11	2	1	5,507	5,723	68	313	10	3	394	672	64	0
Baylor	0	130	28	4	2	0	164	59	0	2	0	1	3	3	1	0
Clay	306±	310	112	19	2	0	749	600	6	10	0	1	17	9	7	0
Cooke	4	237	98	9	1	0	349	339	4	9	2	0	15	10	7	0
Foard	0	5	11	13	1	1	31	17	0	0	0	0	0	4	1	0
Hardeman	0	13	5	5	2	0	25	0	0	0	0	0	0	0	0	1
Knox	0	3	4	5	2	0	14	0	0	0	0	0	0	0	0	1
Montague	1	123	101	18	0	0	243	749	1	6	11	0	18	43	9	0
Wichita	2,049±	4,823	821	15	6	0	7,714	10,701	49	54	9	2	114	88	34	0
Wilbarger	2	229	568	21	2	0	822	1,805	2	20	17	0	39	63	9	0
Total	3,430	10,111	1,935	120	20	2	15,618	19,993	130	414	49	7	600	892	132	2

Continuation of this work is assured for the coming year and results to date have shown that the expenditure is entirely justified.

OUTLOOK FOR 1935

In 1934 the production for the district increased about three million barrels over the 1933 figure, or by approximately the amount of the increase in Archer County. The remaining fields, thanks to acid treatment and to routine development, just about held their own. It is believed that the year 1935 will show a recovery somewhat higher than 1933, but lower than 1934. Routine drilling may be expected to continue during the year, with a gradual tapering off of development in the "Lime" area of Archer County. The North Texas district is far from "through"; and numerous, although perhaps unimportant, discoveries in both wildcat and semiproven areas, together with the development of production in lower horizons as yet unexplored, will maintain the production of North Texas at or above its present rate for many years to come.

Oil Production and Development in North Central Texas in 1934

By T. F. Petty*

(New York Meeting, February, 1935)

Oil and gas production in North Central Texas has been found in sands and limestones in the Cisco, Canyon, Strawn and Bend series of Pennsylvanian age and in lime of pre-Pennsylvanian age. Production ranges in depth below the surface from 150 to 4500 ft.; a few wells have been drilled to depths in excess of 5500 ft. and penetrated rocks of pre-Cambrian age. In Table 1, the average depth of the pools is shown. No mention, however, is made in this table of approximately 30,000 bbl. of oil produced in Callahan County from a pre-Pennsylvanian pay, presumably the Ellenberger, and an excess of 1,000,000 bbl. of oil produced from limestone, which has been identified as Silurian in the south part of Young County. This well is being produced at the present time. In Table 1 a great many pools of minor importance are listed, which are merely productive spots, and throughout the various producing counties there are numerous similar spots, which might be listed as pools. Their production, however, is listed in the county totals.

In Table 2, the totals of the oil wells, gas wells, and dry holes drilled before Jan. 1, 1935, include only wells on which records are available to the writer. In Brown, Callahan and Shackelford counties 2924 very shallow wells (150 to 600 ft. deep) have been drilled, on which the record is not available. Possibly there are other wells that were drilled before the district was adequately scouted. No classification as to the depths of this total of 30,644 wells is available at present.

Initially, nearly all the oil wells of North Central Texas produced gas, and several areas producing dry gas have been partly developed. A number of casinghead gasoline plants strip the gasoline from the gas produced with the oil, and the manufacture of carbon black is an important industry in Stephens County. Dry and residue gas are marketed through systems serving the various towns of the district, San Angelo to the southwest and the cities of Forth Worth and Dallas to the east. Considerable gas is used in repressuring several pools, the most important of which are the Stover of Brown County and the Cook of Shackelford County. During the past year, 32 gas wells were completed, adding a

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* Humble Oil & Refining Co., Cisco, Texas.

TABLE 1.—*Oil Production in North Central Texas*

Line Number	Field, *County*	Age in Years to End of 1934	Area Proved, Acres	Total Oil Production, Bbl.			
			Oil	To End of 1934	During 1933	During 1934	Daily Average durnig Nov., 1934
1	Bull-Alcorn, *Brown*	7	100	106,661	*y*	10,121	14
2	Byler, *Brown*	8	290	773,478	*y*	65,260	90
3	Byrd-Store, *Brown*	14	250	375,841	*y*	9,534	25
4	Childress, *Brown*	7	180	659,536	*y*	28,116	83
5	Clark-Buffalo, *Brown*	7	460	715,108	*y*	22,802	58
6	Cross-Cut, *Brown*	13	2,300	5,619,617	*y*	170,875	439
7	Fry, *Brown*	9	940	7,287,699	152,140	133,578	314
8	George, *Brown*	7	200	657,527	*y*	23,330	74
9	Smith-Ellis, *Brown*	8	450	2,068,689	*y*	37,019	103
10	Stover, *Brown*	8	1,500	6,290,910	236,551	221,465	585
11	Total		12,200	26,689,741*y*	851,447	821,618	2,102
12	Baum, *Callahan*	9	500	780,419	*y*	37,065	94
13	Hatchett, *Callahan*	7	375	1,048,985	*y*	86,013	197
14	Isenhour, *Callahan*	11	600	1,906,153	*y*	66,684	170
15	Moutray, *Callahan*	8	400	1,963,884	*y*	150,241	375
16	Total		11,250	11,604,346	631,516	617,636	1,582
17	Burkett (Shallow), *Coleman*	10	850	1,919,309	*y*	121,391	315
18	Burkett (Deep), *Coleman*	4	200	590,448	132,721	64,951	153
19	Dibbrell, *Coleman*	7	170	298,215	*y*	15,330	48
20	Eastland, *Coleman*	6	270	1,780,409	*y*	64,689	165
21	Jennings, *Coleman*	7	135	420,002	*y*	18,714	63
22	Overall, *Coleman*	8	200	1,024,726	71,565	63,505	166
23	Santa Anna, *Coleman*		150	378,765	*y*	12,901	36
24	Stewardson, *Coleman*	4	180	306,423	*y*	34,159	99
25	Total		3,050	8,083,937	617,134	496,197	1,362
26	Sipe Springs, *Comanche*	15	800	1,325,786	21,037	22,271	56
27	Hilburn, *Eastland*	15	400	1,073,799	*y*	10,400	27
28	Mangum, *Eastland*	12	300	587,054	*y*	80,391	211
29	Pioneer, *Eastland*	15	1,400	5,061,487	*y*	133,505	344
30	Kamsour, *Eastland*	9	250	1,336,790	*y*	37,908	101
31	Total		29,850	69,225,992	904,595	1,002,957	2,670
32	Desdemona, *Eastland, Erath, Comanche*	16	6,175	22,234,504	291,336	238,524	587
33	Royston, *Fisher*	6	1,680	4,146,119	965,457	1,625,413	5,298
34	Moody, *Haskell*	7	40	79,981	10,136	8,173	21
35	Higgs, *Jones*		40	40,594	*y*	2,254	5
36	King, *Jones*		105	126,547	*y*	22,915	57
37	Noodle Creek, *Jones*	7	1,030	5,484,673	619,830	598,328	1,124
38	Sayles, *Jones*	2	100	52,291	*y*	27,838	96
39	Sellars, *Jones*	1	40	10,859	*y*	10,754	56
40	Total		1,345	5,724,996	679,393	669,199	1,416
41	Dalton, *Palo Pinto*	13	160	334,452	*y*	4,665	10
42	Hart, *Palo Pinto*	14	600	750,669	*y*	3,697	9
43	Strawn, *Palo Pinto*	20	1,150	2,611,393	*y*	71,555	187
44	Total		2,400	4,207,530	130,788	130,475	343
45	Ladd-McMillan, *Runnels*	8	170	571,500	80,512	372,493	1,163
46	Cook, *Shackelford*	9	1,300	11,943,433	1,243,700	801,973	2,062
47	Frye, *Shackelford*	9	115	278,459	*y*	13,139	35
48	Hope, *Shackelford*	11	220	1,006,449	*y*	67,476	227
49	Ibex, *Shackelford*	13	1,240	2,256,095	*y*	44,404	102
50	Bluff-Creek, *Shackelford*	4	300	538,017	*y*	288,649	848
51	Newell, *Shackelford*	9	315	557,955	*y*	128,000	312
52	Petroleum Producers, *Shackelford*	5	100	95,356	*y*	9,552	18
53	Simmons-Harvey, *Shackelford*	9	90	154,763	*y*	42,012	216
54	Tannehill-Matthews, *Shackelford*	7	250	1,671,425	*y*	121,100	389
55	Total		11,650	26,415,101*y*	1,167,014	2,011,797	5,460
56	Curry, *Stephens*	14	2,580	9,024,838	*y*	114,011	300
57	Strawn, *Stephens*	17	850	4,140,619	*y*	104,080	257
58	Total		48,000	118,765,883*y*	1,869,007	2,009,754	5,192
59	*Taylor County*, Total	6	170	153,636	25,781	39,839	77
60	Woodson, (Deep), *Throckmorton*	10	260	1,542,836	140,041	147,764	347
61	Woodson (Shallow), *Throckmorton*	9	120	578,464	36,730	46,535	108
62	Total		1,115	2,613,679	234,596	241,147	541

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age in Years to End of 1934	Area Proved, Acres	Total Oil Production, Bbl.			
			Oil	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934
63	Bunger, *Young*	13	1,040	3,523,116	85,036	89,333	220
64	Graham, *Young*	8	380	1,557,981	81,119	54,234	132
65	Herron City, *Young*	13	500	1,522,480	20,249	19,324	43
66	Kisinger, *Young*	5	410	1,839,190	219,395	206,399	442
67	South Bend, *Young*	17	1,440	9,718,463	198,493	176,027	451
68	North Half, *Young*	10	4,471	20,529,092	1,962,982	2,242,275	5,500
69	Total		12,721	48,178,316*y*	3,041,752	3,593,897	6,489
70	Antelope, *Jack*		330	256,594	23,515	22,429	40
71	Bryson, *Jack*		600	3,083,125	287,952	277,748	828
72	Buttram, *Jack*		760	2,097,868	172,212	202,487	532
73	Buttram-Boyd, *Jack*		10	9,645	0	0	0
74	Total		1,700	5,447,232	483,679	502,664	1,400
75	Totals		144,316	355,469,279	12,005,180	14,341,413	34,177

potential production of 153,000,000 cu. ft. The total gas potential of the entire district is not available but it is considerably more than the present market outlet. There is little wastage, as most of the dry gas wells are shut in and the market takes care of that produced with oil.

During 1934, there were drilled in North Central Texas 419 oil wells, with an initial production of 40,600 bbl. daily. Two hundred seventy-five wells which produced from limestone pay were treated with acid, with an increased potential of 12,557 bbl. Production has averaged about 35,000 bbl. daily, about 98 per cent of the wells being marginal and produced under the Texas Marginal Well Law, with additional allowable being based on a small percentage in excess of the marginal well allowable of 10 bbl. from wells less than 2000 ft. deep, 20 bbl. from wells 2000 to 3300 ft. deep, and 25 bbl. from wells deeper than 3300 ft. The total potential of the district is estimated at 50,000 bbl. daily.

The most important developments during the year are as follows: in Brown County, a new discovery was made northeast of Brownwood, which might prove to be a small pool in the lower Bend limestone; three failures to find pre-Pennsylvanian production in Callahan County were recorded; two such failures were recorded in Eastland County; in Fisher County, the Royston pool reached a new peak of 5298 bbl. daily during November from 63 wells, 22 of which were completed during 1934; the Sellars pool was discovered in southeastern Jones County, and a new well was completed 1½ miles southwest of the Higgs pool; in December, in drilling for water, 5½ miles west of Mercury in McCulloch County, oil which flowed 25 bbl. in the first 24 hr., from a Strawn sand 670 ft. below the surface, was encountered, the discovery of which promises to add McCulloch to the list of producing counties; production has been maintained at about 5000 bbl. daily in Stephens County by the use of acid, and

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.	Number of Wells Producing Oil at End of 1934	Average Depth, Ft.	Character of Oil Approx. Average during 1934		Producing Rock			
	Per Acre to End of 1934[b]		Bottoms of Productive Wells	Gravity A.P.I. at 60° F. Maximum	Minimum	Name	Age[g]	Character[h]	Structure[i]
1	1,066	12	1,150	44	40	Fry sand	Pen	S	ML, N
2	2,667	37	1,300	44	40	Fry sand	Pen	S	ML, N
3	1,503	11	2,450	39	37	Bend	Pen	L	A
4	3,664	67	800	34	33	Childress sand	Pen	S	ML, N
5	1,554	53	1,150	44	40	Fry sand	Pen	S	ML, N
6	2,443	321	1,200	44	40	Cross Cut sand	Pen	S	ML, N
7	7,754	152	1,300	44	40	Fry sand	Pen	S	ML, N
8	3,287	47	1,300	44	40	Fry sand	Pen	S	ML, N
9	4,597	65	1,300	44	40	Fry sand	Pen	S	ML, N
10	4,194	263	1,200	44	40	Blake sand	Pen	S	ML, N
11	2,187	1,414		44	30				
12	1,560	55	1,700	44	40	Cross Plains sand	Pen	S	ML, N
13	2,794	93	400	36	34	Moutray sand	Pen	S	ML
14	3,176	167	700	36	34	Isenhour sand	Pen	S	ML
15	4,909	114	750	36	34	Moutray sand	Pen	S	ML
16	1,032	1,441		39	32				
17	2,259	169	400	35	34	Burkett sand	Pen	S	ML
18	2,952	39	1,550	44	40	Cross Cut sand	Pen	S	ML, N
19	1,754	14	1,900	44	40	Gwinnup sand	Pen	S	ML, N
20	6,594	44	2,000	43	41	Gwinnup sand	Pen	S	ML, N
21	3,111	25	1,150	44	40	Fry sand	Pen	S	ML
22	5,123	29	2,200	44	40	Canyon-Strawn	Pen	S	A
23	2,525	9	1,500	44	40	Fry sand	Pen	S	ML, N
24	1,702	17	1,450	44	40	Fry sand	Pen	S	ML, N
25	2,650	425		44	34				
26	1,657	106	300	37	34	Strawn	Pen	S	A
27	2,684	3	3,100	38	35	Bend	Pen	L	MN
28	1,957	54	2,100	*y*	*y*	Strawn	Pen	S	ML
29	3,616	69	2,450	42	38	Caddo lime	Pen	L	AF
30	5,347	12	3,600	39	37	Bond sand	Pen	S	N
31	2,319	603		42	*y*				
32	3,576	114	2,750	39	37	Desdemona sand	Pen	S	A
33	1,645	63	3,100	41	38	Royston	Pen	L	A
34	1,999	6	1,800	37	36	Hope	Pen	S	N
35	1,015	2	1,800	38	36	Petroleum Producers sand	Pen	S	N
36	1,205	7	2,000	38	36	Petroleum Producers sand	Pen	S	A
37	5,531	96	2,450	40	38	Noodle Creek lime	Pen	L	MC, N
38	523	4	1,950	38	36	Petroleum Producers sand	Pen	S	ML
39	271	3	1,650	38	36	Tannehill sand	Pen	S	ML
40	4,387	115		*y*	*y*				
41	2,090	12	3,950	*y*	*y*	Bend	Pen	L	N
42	1,251	4	3,200	*y*	*y*	Bend	Pen	L	N
43	2,270	159	1,850	*y*	*y*	Strawn sands	Pen	S	ML, N
44	1,753	214		*y*	*y*				
45	3,572	16	2,550	48	43	McMillan sand	Pen	S	ML, N
46	9,187	349	1,300	38	37	Cook sand	Pen	S	ML, N
47	2,421	56	450	36	34	Fry sand	Pen	S	ML, N
48	4,575	53	1,500	39	37	Hope sand	Pen	S	ML, N
49	1,819	44	3,500	38	36	Caddo lime	Pen	L	N
50	1,790	49	1,600	40	38	Petroleum Producers sand	Pen	S	ML, N
51	1,361	68	1,100	38	36	Tannehill sand	Pen	S	ML, N
52	953	10	1,650	40	38	Petroleum Producers sand	Pen	S	N
53	2,211	7	1,700	40	38	Petroleum Producers sand	Pen	S	N
54	6,686	65	1,150	41	39	Tannehill sand	Pen	S	ML, N
55	2,253	1,679		40	35				
56	3,498	61	3,100	38	36	Caddo lime	Pen	L	A
57	4,871	103	1,850	39	*y*	Strawn sands	Pen	S	ML, N
58	2,474	785		38	36				

[b] Footnotes to column headings and explanation of symbols are on page 249.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl. Per Acre to End of 1934[b]	Number of Wells Producing Oil at End of 1934	Average Depth, Ft. Bottoms of Productive Wells	Character of Oil Approx. Average during 1934, Gravity A.P.I. at 60° F. Maximum	Character of Oil Approx. Average during 1934, Gravity A.P.I. at 60° F. Minimum	Producing Rock: Name	Producing Rock: Age[g]	Producing Rock: Character[h]	Producing Rock: Structure[i]
59	904	9	2,500	38	36	Cisco	Pen	L, S	N
60	5,934	10	3,900	39	37	Caddo lime	Pen	L	A
61	4,820	11	1,800	38	36	Canyon, Strawn sands	Pen	S	ML
62	2,344	173		39	33				
63	3,387	54	2,600	38	36	Strawn	Pen	S	A
64	4,100	14	3,900	38	36	Bend, Strawn	Pen	S, L	A
65	3,045	20	2,600	38	36	Strawn	Pen	S	ML, N
66	4,486	41	2,500	38	36				
67	6,749	84	4,200	38	36	Strawn	Pen	S	ML, N
68	4,592	1,544	4,140	39	33	Cisco to Bend	Pen	S, L	ML, N
69	3,787	1,845		40	30				
70	778	70	600	[y]	[y]	Cisco	Pen	S	N
71	5,139	88	3,100	[y]	[y]	Strawn	Pen	S	N
72	2,760	43	2,050	[y]	[y]	Strawn, Bend	Pen	S, L	N
73	964	1	2,425	[y]	[y]	Strawn	Pen	S	N
74	3,145	202		[y]	[y]				
75	2,463	9,210		48	30				

a well in the southern part of the county indicates, if mechanical difficulties are overcome, the probability of producing some pre-Pennsylvanian oil; several new productive spots were discovered in Shackelford County; the Ladd-McMillan pool in Runnels County was extended from 6 to 16 producing wells, reaching a peak production of 1496 bbl. daily during September; and considerable new development of Cisco to Bend production was experienced in Young County.

TABLE 2.—*Summary of Drilling Operations in North Central Texas*
(Figures in body of tabulation represent number of holes.)

County	Completed Prior to January 1, 1935					Completed during 1934				Drilling or Incomplete at End of 1934
	Oil	Gas	Dry	Total	Productive Wells (For Details, See Table 1)	Oil	Gas	Dry	Total	Exploratory
Brown	2,031	131	1,490	3,652	1,414	21	4	32	57	11
Callahan	1,023	91	1,152	2,266	1,441	9	1	27	37	7
Coke	y	y	y	y	0	y	y	y	y	0
Coleman	505	137	755	1,397	425	5	1	26	32	8
Comanche	160	68	211	439	106	1	0	2	3	2
Concho	2	1	46	49	0	0	0	1	1	0
Dallas	0	0	y	y	0	y	y	y	y	y
Denton	0	0	36	36	0	0	0	3	3	0
Eastland	2,236	304	1,185	3,725	603	16	6	12	34	8
Erath[1]	124	70	115	309	114	0	0	0	0	2
Fisher	67	0	69	136	63	22	0	9	31	8
Haskell	6	1	47	54	6	0	0	0	0	0
Hood	0	2	9	11	0	0	0	0	0	0
Jack	303	17	327	647	202	18	3	61	82	7
Jones	141	0	139	280	115	16	0	19	35	6
McCulloch	0	7	53	60	0	0	0	1	1	1
Mills	1	0	14	15	0	0	0	0	0	2
Nolan	0	1	21	22	0	0	0	0	0	0
Palo Pinto	283	173	317	773	214	4	12	6	22	5
Parker	0	2	22	24	0	0	0	6	6	0
Runnels	22	1	54	77	16	14	0	8	22	11
San Saba	0	0	8	8	0	0	0	1	1	0
Shackelford	1,482	73	1,404	2,959	1,679	99	1	75	175	17
Somervell	0	0	3	3	0	0	0	0	0	0
Stephens	2,910	246	1,046	4,202	785	5	1	1	7	1
Tarrant	0	0	y	y	0	0	0	2	2	0
Taylor	13	2	68	83	9	1	0	4	5	1
Throckmorton	320	48	426	794	173	1	3	9	13	4
Wise	0	0	29	29	0	0	0	2	2	1
Young	2,621	38	3,011	5,670	1,845	187	0	15	202	34
Total	14,250	1,413	12,057	27,720	9,210	419	32	322	773	136

[1] Desdemona pool in Erath, Eastland, and Comanche counties.

Oil and Gas Development in the Texas Panhandle for the Year 1934

By T. C. Craig*

(New York Meeting, February, 1935)

For the year 1934, there were 382 oil wells completed for a total initial of 146,965 bbl. Fifty-three wells were deepened for a total increase of 8363 bbl., bringing the total volume of new oil to 155,328 bbl. As of Jan. 1, 1934, the daily potential of the field as determined by the Texas Railroad Commission was 159,740 bbl. Of this amount 26,429 bbl. is "marginal oil," and 2682 bbl. is exempt on account of water. In December, 1934, the daily potential was established by the Railroad Commission as being 297,501 bbl. with a daily allowable of 56,800 bbl. Of this amount 31,993 bbl. is "marginal oil," and 2183 bbl. is exempt on account of water.

There has been no field-wide test made during the year, and as a result the rated potential of the field is in all probability much higher than the actual potential. As each new well comes in, a five-day test is made under the supervision of the Railroad Commission. The potential thus established is added to the field potential and shares its pro rata part of the market outlet, which is the allowable production, no allowance

Table 1.—*Oil and Gas Production in Texas Panhandle*

Line Number	Count	Age, Years to End of 1934	Area Proved, Acres			Total Oil Production, Bbl.				Average Oil Production, Bbl.	
			Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov. 1934	Per Acre to End of 1934[b]	Per Well Daily during Nov. 1934
1	Carson	13	15,000	187,240	202,240	21,314,012	1,735,200	1,910,765	4,658	1,421	17.8
2	Gray	9	39,000	102,100	141,100	110,006,055	10,395,226	20,561,355	32,440	2,821	31.0
3	Hartley	6	0	1,200	1,200						
4	Hutchinson	12	47,800	154,672	202,472	103,740,407	4,000,410	4,450,476	12,098	2,170	16.3
5	Moore	8	1,000	320,000	321,000	2,387,582	351,971	321,677	1,083	2,387	77.4
6	Potter	15	0	107,520	107,520	33,822					
7	Wheeler	9	7,500	140,900	148,400	3,263,918	149,840	1,368,945	6,411	435	49.3
8	Total		110,300	1,013,632	1,123,932	240,745,796	16,632,647	28,613,218			

[a] Footnotes for table heads and explanation of symbols are on page 249.

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* Phillips Petroleum Co., Amarillo, Texas.

being made for decline. While the actual potential of the field is fictitious, for all practical purposes, it makes very little difference from a field-wide viewpoint, on account of the limited market outlet.

Dry Gas.—There were 67 gas wells drilled during the year with a total initial open flow of 2,320,800,000 cu. ft.; 38 depleted oil wells were plugged back for gas with a total initial open flow of 229,700,000 cu. ft., increasing the open-flow capacity of the field to approximately 19,000,000,000 cu. ft., exclusive of casinghead gas.

Operating in the field are 17 natural gas pipe lines, 8 of which are local and 9 interstate, which withdrew a daily average of 376,381,912 cubic feet.

Natural Gasoline.—Operating on both casinghead and dry gas are 49 natural gasoline extraction plants with a total daily capacity of 2,287,500,000 cu. ft. The daily average withdrawal for the year was 1,577,257,939 cu. ft. The total gasoline manufactured from these plants during 1934 was 293,055,462 gallons.

The average gallons per thousand has declined 0.18 from that of the preceding year, because of the processing of less casinghead gas and more dry gas, as permitted by the so-called "Sour Gas Law." The "Sour Gas Law" permits the unrestricted use of gas from any gas well up to 25 per cent of its open-flow capacity. Where no market for the residue gas is available, it may be released to the air. On account of the controversial nature of the dispute between the gas pipe line interests and strippers brought about by this law, the writer does not care to go into the matter, except to state that a heated battle of words via newspapers and the radio has ensued since last October. It might appear from the viewpoint of the casual observer that the solution should

TABLE 1.—(*Continued*)

	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							Average Depth Ft.		Pressure, Lb. per Sq. In.[e]		
						During 1934		At End of 1934							Average at End of	
Line Number	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Producing Oil Only	Producing Oil and Gas[e]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Initial	1933[2]	1934
1					500	33	4	86	177	205	468	3,150	3,050	430	381	y
2					1,324	219	7	428	644	166	1,238	3,100	3,000	430	360	y
3					4	0	0	0	0	4	4	3,200	2,900	430	428	y
4					1,414	62	75	436	325	157	918	3,000	2,900	430	327	y
5					100	8	0	13	2	76	91	3,500	3,400	430	416	y
6					42	0	0	0	0	42	42	2,500	2,300	430	420	y
7					408	127	3	107	38	253	398	2,550	2,450	430	382	y
8	4,630,179.5[1]	471,120[1]	715,268.5[1]	2,299[1]	3,792	449	89	1,070	1,186	903	3,159					

[1] Gas figures are composite for field. They are the best available but are subject to correction.

[2] Weighted average rock pressure based on 1,379,816 acres as total area of field (both proven and semiproven areas).

easily be obtained. There is a point of equity on both sides, however, which cannot be overlooked.

Carbon Black.—There are 27 carbon-black plants in the area and one under construction. Twenty-six plants operated throughout the year, consuming a total of 163,983,709,000 cu. ft., or a daily average of 449,270,435 cu. ft. of residue gas from the natural gasoline extraction plants. We have been unable to obtain information concerning the type of black made, or the recoveries, but it is estimated that the average yield is 1.5 lb. per 1000 cu. ft. of gas. Assuming this estimate to be correct, there were 245,975,563 lb. of black manufactured during the year.

Refineries.—The total daily refinery capacity for the Panhandle is now rated at 78,250 bbl. The total oil run to local refineries during the year was 11,000,730 barrels.

Wildcat Operations.—Three wildcat wells were drilled during 1934, all of which were dry. At the close of the year, four wells were still drilling, one of which is in Randall County and now drilling at approximately 5600 ft.; another is in Childress County, drilling at 5200 ft. These wells are the deepest tests to date on the south side of and closely adjacent to the buried Amarillo Mountains. One of the most important wells that has been drilled in the area is the Phillips et al. No. 2 Wilson, sec. 157, block 3-T, T. & NO. Survey, Moore County, Texas, which was abandoned at 8013 ft. in Arbuckle dolomite.

New Development.—Wheeler County came to the front during the year in that there were approximately 5½ miles of additional granite

TABLE 1.—(*Continued*)

Line Number	Character of Oil Approx. Average during 1934					Character of Gas Approx. Average during 1934		Producing Rock			Structure[i]	Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Gravity A.P.I. at 60° F.			Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.[e]	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]			Name	Depth of Hole, Ft.
	Maximum	Minimum	Weighted Average											
1	45	32	39	0.6	M	1,094	0.43	Big Lime Series (Wichita-Albany) Upper Penn (Undifferentiated)	Per Penn	D, Da GW	Af	35		
2	45	31	39	0.4	M	1,103	0.70	Big Lime Series (Wichita-Albany) Upper Penn (Undifferentiated)	Per Penn	D, Da GW	Af	122		
3								Big Lime Series (Wichita-Albany)	Per	D	Af	11		
4	39	29	35	0.8	M	1,106	0.47	Big Lime Series (Wichita-Albany) Upper Penn (Undifferentiated)	Per Penn	D, Da L, GW	Af	34	Arbuckle	5,333
5	36	30	31	0.8	M	1,056	0.30	Big Lime Series (Wichita-Albany) Upper Penn (Undifferentiated)	Per Penn	D L, GW	Af	12	Arbuckle	8,013
6						1,069		Big Lime Series (Wichita-Albany) Upper Penn (Undifferentiated)	Per Penn	D GW	Af	12		
7	44	30	35	0.4	M	1,070	0.28	Big Lime Series (Wichita-Albany) Upper Penn (Undifferentiated)	Per Penn	D, Da GW	Af	54		
8												280		

[e] Dry gas, 30 in. at 60° F.

wash trend developed. A granite wash pool of small size was also developed in the eastern part of the county.

The Texas Company completed its No. 1-C Taylor, in sec. 52, block B-2, H. & GN. Survey, Gray County, for 233 bbl. This well is on the apex of the structure, in an area previously considered to be gas territory only. There is considerable variance among geologists as to whether this opens up another pool, or is just another freak condition for which the Panhandle is noted.

The Humble Oil and Refining Co. No. 1 Logan, in the Pedigo Survey of Hutchinson County, was completed for 44 bbl. per day from the dolomite. This well extends the dolomite trend some 8 miles from the nearest production.

TABLE 2.—*Summary of Drilling Operations in Texas Panhandle*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1935								Completed during 1934							Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes							Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes						Productive Wells (For Details, See Table 1)		
	Total Depths, Ft.								Total Depths, Ft.								
	1000-2000	2000-3000	3000-4000	4000-5000	5000-6000	8000-9000	Total		1000-2000	2000-3000	3000-4000	5000-6000	8000-9000	Total		Within Fields	Exploratory
Armstrong			2	3			5										
Bailey				1			1										
Briscoe				1			1										
Carson	4	8	22		1		35	500			2			2	33	9	
Castro				1			1										
Childress	5	4	4	1	1		15		1					1			1
Collingsworth	3	7	5				15			1				1			1
Cottle		1	2	5	1		9										
Dallam	1	2	1	2			6										1
Deaf Smith	1		1				2		1					1			
Donley			7	1			8										
Floyd				2			2										
Gray	3	45	69	5			122	1324			3			3	219	64	2
Hale	1		1	1			3										
Hall	3	3	3		1		10										
Hansford			2	1			3										
Hartley		2	5	3	1		11	4									
Hemphill			3		1		4										
Hutchinson	2	10	20	1	1		34	1414		1				1	62	27	2
Lamb	1			2			3										
Lipscomb				3	1		4										
Moore	1	3	6		1	1	12	100[1]		1		1	1	3	8[1]	5	
Motley			2	5			7										
Ochiltree	1		1				2										
Oldham		4	4	1	1		10										
Parmer			2		1		3										
Potter		3	5	4			12	42								1	
Randall	1	2	1	1			5										1
Roberts		1		1	1		3										2
Sherman			2	2			4										
Wheeler	13	37	3	1			54	408		10				10	127	35	4
Total	40	132	173	48	12	1	406	3792	2	13	5	1	1	22	449	141	14

[1] Two deep dry tests plugged back for gas.

Drilling.—A new method of drilling through horizons developing large gas flows by pressure equalization was worked out by E. N. Armstrong, engineer for the Shamrock Oil and Gas Co., on wells in Moore County. While the equipment used is not new to the industry, it had not been applied in this field. This method of drilling is a solution for the handling of large gas volumes encountered while drilling through cavernous formations.

Oil and Gas Development in Southwest Texas during 1934*

By Olin G. Bell†, Member A.I.M.E.

(New York Meeting, February, 1935)

The year 1934 in Southwest Texas was marked by aggressive development and exploratory work and resulted in the finding of five new fields and a new producing horizon in one of the older fields. This activity is the result of a reasonable market outlet for production, on both oil and gas, and the fact that drilling and operating costs are reasonable and that possibilities of finding new productive areas are rather high. A large part of the area is prospective and very little, if any, satisfactory surface geological work can be done. This, together with the possibility of finding new productive areas, stimulates wildcatting throughout the counties under discussion. Development work continued actively in all of the newer fields.

Exploratory work was most intense in Duval, McMullen, Starr and Zapata counties. The activity in Duval and McMullen counties was the result of persistent efforts to find new trends of production similar to and perhaps associated with the Government Wells group of fields. The activity in Starr and Zapata counties was stimulated by the discovery of the Sam Fordyce field in Hidalgo County as well as the continued effort to find new productive trends southeastward from some of the older fields in northeastern Zapata County and western Jim Hogg County.

Statistics on production are shown in Tables 1 and 2.

New Fields

Lopeño.—The Lopeño gas field in the southwestern part of Zapata County was opened in August, 1934, by R. B. Morrison No. 1 Ramirez. This is an anticlinal structure mapable in Claiborne beds and the producing horizon is the Queen City sand at 2100 ft. in the Upper Mt. Selman. At the close of the year only two gas wells had been completed but drilling operations were in progress on several other wells and a gas line was being laid to the field so that withdrawals from the area will begin early in 1935.

Comitas.—The Comitas field was opened by Merle Gunby No. 1 Haynes in a sand at 800 ft. in an area southwest of the Escobas field. The discovery well had an initial production of only about 16 bbl. of oil

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per day. One other well drilled in this immediate vicinity was dry and it rather appears that the productive area here will be small.

Labbé.—The Labbé field in northern Duval County was discovered by the Magnolia Petroleum Co. No. 1 Labbe, completed as a 30 million cubic foot gas well in a 2400-ft. sand, Nov. 26, 1934. This is the first and only well drilled in this immediate area. There is no market outlet for this gas at present but this discovery probably opens an important producing area in this part of the district. The producing horizon is in the McElroy member of the Jackson.

Colmena.—The Colmena field in western Duval County was opened by Mills Bennett No. 1 Duval County Ranch Co. as a 15 million cubic foot gas well, Dec. 7, 1934 in a 1500-ft. sand, Whitsett (Upper Jackson) in age. There is no market outlet for this production at the present time. This well likewise apparently opened a producing area in this part of the district.

Loma Novio.—The Loma Novio field, in northern Duval County and east of the Government Wells field, was opened by the Humble Oil & Refining Co. No. 1 Ruiz, completed Dec. 24, 1934, in a 2700-ft. sand. This sand is McElroy (Middle Jackson) in age. While only one well had been completed at the close of the year, activity by several operators was started early in 1935, and this field probably will undergo rather active development during the year.

Cole.—A new producing horizon in the Cole field of Webb and Duval counties was opened by the United Production Corporation in July of 1934. The pay sand is at 3400 ft. and is in the Upper Saline Bayou (Lower Yegua). Up to the close of the year 21 wells had been completed and the daily average production was approximately 1300 bbl. under proration. The gravity of the oil is 41.7°.

PRORATION

While theoretically all of this area was under proration during the year, actual restriction was confined only to the newer fields, particularly the Government Wells group and the Cole field, which were fields capable of producing much greater quantities than the allowable. In the other fields the allowable set was essentially the same as the potential output of the field.

GAS DEVELOPMENT

Southwest Texas has long been an important gas-producing area and there has been considerable effort to develop new gas production as well as oil production in order to keep pace with the demands for gas in this territory. This has resulted in considerable gas development work in the Martinez field of Zapata County and the gas areas of the other fields.

TABLE 1.—*Oil and Gas Production in Southwest Texas*

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres			Total Oil Production, Bbl.				Average Oil Production, Bbl.		
			Oil	Gas	Total	To End of 1934[1]	During 1933	During 1934[1]	Daily Average during Nov., 1934	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934
1	Reiser *Webb*	26	0	1,280	1,280	0	0	0	0	0	0	0
2	Jennings. *Zapata*	21	0	320	320	0	0	0	0	0	0	0
3	Crowther, *McMullen*	16	160	0	160	*y*	*y*	*y*	*y*	*y*	*y*	*y*
4	Calliham, *McMullen*	15	210	220	430	763,687	29,459	13,788	35	3,636	279	1.0
5	Charco Redondo, *Zapata*	15	336	0	336	133,073	9,407	4,521	19	396	49	0.2
6	Mirando Valley, *Zapata*	13	115	120	235	607,759	11,578	10,742	29	5,285	352	0.9
7	Carolina-Texas, *Webb*											
8	1,200-ft. sand	13	0	80	80	0	0	0	0	0	0	0
9	2,000-ft. sand	12	0	480	480	0	0	0	0	0	0	0
10	2,600-ft. sand	9	70	480	550	128,536	9,800	10,636	30	1,836	229	7.2
11	3,000-ft. sand	11	40	400	440	153,573	14,703	15,448	31	3,836	213	5.0
12	Total		110	1,440	1,550	282,109	24,503	26,084				
13	Mirando City, *Webb*	13	1,430	420	1,850	8,273,829	217,734	163,664	413	5,785	526	3.6
14	Aviator, *Webb*	12	955	320	1,275	5,197,067	198,364	175,042	474	5,448	495	2.3
15	Leaseholders, *Webb*	12	10	0	10	*x*	0	0	0	*x*	*x*	0
16	Henne-Winch-Fariss, *Jim Hogg*	10	715	440	1,155	3,261,103	3,752	11,944	38	4,560	507	3.1
17	Cole, *Webb-Duval*											
18	1,700-ft. sand	10	65	4,000	4,065	155,186	19,620	14,903	34	2,387	298	6.8
19	2,300-ft. sand	7	0	1,280	1,280	0	0	0	0	0	0	0
20	2,800-ft. sand	4	120	0	120	328,716	65,684	50,734	139	2,740	274	27.0
21	2,900-ft. sand	1	0	80	80	0	0	0	0	0	0	0
22	3,400-ft. sand	1	640	60	700	124,039	0	124,039	1,359	194	13	90
23	Total		825	5,420	6,245	607,941	85,304	189,676				
24	Randado, *Jim Hogg*	9	733	150	883	3,939,402	140,767	139,350	355	5,394	600	3.1
25	Piedras Pintas, *Duval*	9	30	0	30	112,784	0	18,631	133	3,756	187	66.0
26	Kohler, *Duval*	8	170	1,840	2,010	416,47	55,384	49,106	144	2,450	350	18.0
27	Alworth, *Jim Hogg*	8	40	0	40	25,272	3,248	1,223	5	631	105	1.2
28	Albercas, *Webb*	7	320	160	480	2,370,036	67,123	50,997	113	7,406	435	3.5
29	West Cole, *Webb*	7	330	960	1,290	2,800,005	268,875	241,237	614	8,484	771	9.9
30	Cuellar, *Zapata*	7	315	160	475	2,362,774	110,568	51,290	112	7,500	937	3.6
31	Driscoll, *Duval*											
32	2,400-ft. sand	7	0	12	120	0	0	0	0	0	0	0
33	2,900-ft. sand	6	120	60	180	408,706	54,168	25,903	34	3,400	560	10.4
34	3,300-ft. sand	1	80	0	80	0	0	0	0	0	0	0
35	3,400-ft. sand	1	40	0	40	17,604	0	17,604	92	440	72	92
36	Total		240	180	420	426,310	54,168	43,507				
37	Government Wells, *Duval*	6	7,840	320	8,160	16,228,023	4,170,277	6,597,107	23,017	1,988	104	36.0
38	Palangana, *Duval*	6	20	0	20	2,223	0	0	0	11	*x*	0
39	Martinez, *Zapata*	6	0	600	600	0	0	0	0	0	0	0
40	Roma, *Starr*	5	10	80	90	16,750	3,720	2,328	16	1,675	55	16
41	Escobas, *Zapata*											
42	1,000-ft. sand	5	0	120	120	0	0	0	0	0	0	0
43	1,200-ft. sand	5	1,260	480	1,740	3,732,236	770,037	674,278	1,683	2,962	185	9.1
44	1,400-ft. sand	5	1,800	120	1,920	1,172,738	125,356	112,080	245	652	91	5.0
45	Total		3,060	720	3,780	4,904,974	895,393	786,358	1,928			
46	S.R.C., *Duval*	4	80	0	80	180,028	28,633	35,595	79	2,250	321	15.8
47	Los Olmos, *Starr*	4	160	0	160	346,945	153,054	95,098	26	2,168	197	0.4
48	Wentz, *McMullen*	3	0	80	80	0	0	0	0	0	0	0
49	Sarnosa, *Duval*	3	400	20	420	886,514	353,582	338,333	849	222	55	8.2
50	Rio Grande City, *Starr*	3	22	0	22	74,258	31,510	24,820	61	3,375	422	10.0
51	Jacobs, *McMullen*	3	420	0	420	376,296	122,873	209,221	710	896	47	16.0
52	Laurel, *Webb*	3	220	320	540	555,720	341,212	80,142	209	2,526	281	10.0
53	Villa, *Zapata*	3	0	80	80	0	0	0	0	0	0	0
54	Clark-Cowden, *Jim Hogg*	3	0	40	40	0	0	0	0	0	0	0
55	Smith-Hunter, *Duval*	2	0	40	40	0	0	0	0	0	0	0
56	Kobler-North, *Duval*											
57	1,700-ft. sand	1	0	80	80	0	0	0	0	0	0	0
58	2,400-ft. sand	2	10	320	330	0	0	0	0	0	0	0
59	Total		10	400	410	0	0	0	0			
60	Moca, *Webb*	2	80	0	80	211,260	100,579	110,681	327	2,640	240	29.8
61	Blas Uribe, *Zapata*	2	0	80	80	0	0	0	0	0	0	0
62	Ignacio, *Duval*	2	10	0	10	0	0	0	0	0	0	0
63	Cuevitas (Guerra), *Starr*	2	360	40	400	73,950	1,960	71,990	510	205	9	57
64	Hoffman, *Duval*	1	0	40	40	0	0	0	0	0	0	0
65	Barbacoas, *Starr*	1	10	160	170	3,865	0	3,865	13	387	25	6.5
66	Eagle Hill, *Duval*											
67	1,500-ft. sand	1	200	0	200	199,786	18,622	181,164	450	996	99	25.0
68	2,100-ft. sand	1	20	0	20	5,976	0	5,976	29	298	29	29.0
69	Total		220	0	220	205,762	18,622	187,140	479			
70	Lopeño, *Zapata*	0	0	120	120	0	0	0	0	0	0	0
71	Comitas, *Zapata*	0	50	0	50	0	0	0	0	0	0	0
72	Labbé, *Duval*	0	0	40	40	0	0	0	0	0	0	0
73	Colmena, *Duval*	0	0	40	40	0	0	0	0	0	0	0
74	Loma Novio, *Duval*	0	80	0	80	0	0	0	0	0	0	0
75	Total		20,096	16,650	36,746	55,646,190	7,501,649	9,733,480				

[b] Footnotes for column heads and explanation of symbols are on page 249.

[1] Oil and gas production for December, 1934, estimated. [2] Naphthalene.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.: To End of 1934	Total Gas Production: During 1933	Total Gas Production: During 1934[1]	Total Gas Production: Maximum Daily during 1934	Number of Oil and/or Gas Wells: Completed to End of 1934	During 1934: Completed	During 1934: Abandoned	At End of 1934: Temporarily Shut Down	At End of 1934: Producing Oil Only	At End of 1934: Producing Gas Only	At End of 1934: Total Producing	Average Depth, Ft.: Bottom of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1934, Number of Wells: Flowing	Pumping	Gas Lift	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of 1933	Average at End of 1934
1	y	0	0	0	15	0	0	0	0	0	0	800	650	0	0	0	y	0	0
2	y	570.1	285.2	y	25	0	0	0	0	2	2	1,240	1,220	0	0	0	y	251	225
3	0	0	0	0	y	0	0	0	y	0	y	y	y	0	y	0	y	0	0
4	y	y	y	y	y	1	0	0	36	y	36	1,000	700	0	36	0	y	y	y
5	0	0	0	0	155	2	0	0	138	0	138	173	165	0	138	0	0	0	0
6	y	8.6	10.4	y	39	0	0	0	16	1	17	1,540	1,525	0	16	0	600	275	250
7																			
8	y	0	0	0	2	0	0	0	0	0	0	1,305	1,270	0	0	0	y	0	0
9	y	y	y	y	24	0	0	0	0	y	y	2,130	2,120	0	0	0	645	y	y
10	y	y	y	y	18	0	0	0	4	12	16	2,605	2,597	0	4	0	900	260	225
11	y	y	y	y	18	0	0	0	6	10	16	3,198	3,180	0	6	0	1,125	260	230
12	y	1,185.0	1,247.5	y	62	0	0	0	10	22	32			0	10				
13	y	1.1	1.2	y	294	0	20	0	113	1	114	1,741	1,730	0	113	0	y	y	y
14	y	0	0	0	217	0	0	0	197	0	197	1,730	1,719	0	197	0	y	0	0
15	0	0	0	0	2	0	0	0	0	0	0	1,015	1,000	0	0	0	x	0	0
16	y	309.2	0	0	191	0	0	0	12	0	12	2,149	2,140	0	12	0	500	167	150
17																			
18	y	y	y	y	123	0	0	0	5	82	87	1,730	1,722	0	5	0	600	290	250
19	y	y	y	y	32	0	0	0	0	22	22	2,324	2,314	0	0	0	900	300	260
20	0	0	0	0	5	0	0	0	5	0	5	2,810	2,800	5	0	0	y	y	y
21	y	y	y	y	2	2	0	0	0	2	2	2,960	2,951	0	0	0	1,125	0	1,125
22	0	0	0	0	21	21	0	0	21	0	21	3,414	3,400	21	0	0	1,100	0	1,100
23	y	8,693.0	9,409.7	y	183	23	0	0	31	106	137			26	5				
24	y	100.0	13.1	y	189	0	20	0	114	1	115	1,229	1,220	0	114	0	500	55	45
25	0	0	0	0	4	2	0	0	2	0	2	3,626	3,600	2	0	0	640	0	640
26	y	2,296.0	2,118.4	y	65	0	0	0	8	29	37	1,850	1,843	0	8	0	650	287	240
27	0	0	0	0	10	0	0	0	4	0	4	1,026	1,020	0	4	0	450	0	0
28	y	191.0	0	0	79	0	5	0	32	0	32	2,175	2,158	0	32	0	600	191	150
29	y	605.2	583.9	2.8	107	8	8	0	62	14	76	2,346	2,335	0	62	0	710	290	260
30	y	13.0	0	0	80	0	22	0	31	0	31	1,340	1,332	0	31	0	500	305	250
31																			
32	407.1	137.6	135.9	0.4	3	0	0	0	0	3	3	2,465	2,459	0	0	0	900	775	700
33	133.4	45.8	42.0	0.2	6	0	0	0	3	1	4	2,890	2,884	0	3	0	960	950	940
34	0	0	0	0	2	2	0	0	0	2	2	3,380	3,370	0	0	0	1,150	0	1,150
35	0	0	0	0	1	1	0	0	1	0	1	3,448	3,387	1	0	0	1,185	0	1,185
36	540.5	183.4	177.9		12	3	0	0	4	6	10			1	3				
37	y	345.0	340.6	y	689	305	31	0	624	6	630	2,350	2,331	245	310	69	800	550	500
38	0	0	0	0	4	0	0	0	0	0	0	550	540	0	0	0	0	0	0
39	y	349 3	2,496.0	y	27	6	8	0	0	14	14	1,870	1,860	0	0	0	660	269	260
40	0	0	0	0	6	0	0	5	1	0	6	3,590	3,560	0	1	0	y	y	y
41																			
42	y	y	y	y	2	0	0	0	0	2	2	1,012	1,000	0	0	0	y	y	y
43	y	y	y	y	220	17	14	0	195	13	208	1,240	1,226	0	195	0	540	225	200
44	y	y	y	y	69	0	0	0	49	3	52	1,440	1,433	0	49	0	y	y	y
45	y	y	217.9	y	291	17	14	0	244	18	262			0	244				
46	0	0	0	0	6	0	0	0	5	0	5	1,727	1,720	0	5	0	y	y	y
47	0	0	0	0	82	21	0	0	64	0	64	380	369	0	64	0	y	0	0
48	y	y	y	y	2	0	0	0	0	2	2	380	370	0	0	0	y	y	y
49	27.5	0	0	0	30	3	0	0	27	3	27	2,455	2,415	0	27	0	600	y	475
50	0	0	0	0	7	0	1	0	6	0	6	1,463	1,455	0	6	0	y	y	y
51	0	0	0	0	46	29	0	0	44	0	44	975	956	0	44	0	y	y	y
52	525.7	233.0	288.7	0 3	8	0	16	0	21	3	24	2,220	2,211	0	21	0	600	365	300
53	0	0	0	0	2	0	0	2	0	0	2	1,600	1,580	0	0	0	500	y	y
54	0	0	0	0	1	0	0	1	0	0	1	2,262	2,246	0	0	0	500	y	y
55	0	0	0	0	1	0	0	1	0	0	1	1,931	1,910	0	0	0	750	y	y
56																			
57	178.8	48.1	130.7	y	1	0	0	0	0	1	1	1,739	1,736	0	0	0	600	560	550
58	y	y	y	y	7	2	0	0	0	7	7	2,452	2,438	0	0	0	850	y	y
59	y	y	y	y	8	2	0	0	0	8	8			0	0				
60	0	0	0	0	13	2	2	0	11	0	11	861	850	0	0	0	y	y	y
61	0	0	0	0	2	2	0	2	0	0	2	1,845	1,835	0	0	0	500	0	0
62	0	0	0	0	2	0	0	0	1	1	2	2,138	2,127	0	1	0	500	y	y
63	10.4	10.4	0	0	17	7	2	0	9	6	15	2,242	2,220	9	0	0	800	800	800
64	0	0	0	0	2	1	0	0	0	2	2	2,757	2,751	0	0	0	975	y	y
65	0	0	0	0	6	6	0	0	2	4	6	2,455	2,440	0	2	0	960	y	y
66																			
67	0	0	0	0	19	10	0	0	18	1	19	1,480	1,490	8	10	0	500	y	y
68	0	0	0	0	1	1	0	0	1	0	1	2,147	2,136	0	1	0	y	0	y
69	0	0	0	0	20	11	0	0	19	1	20			8	11				
70	0	0	0	0	2	2	0	2	0	0	2	2,180	2,132	0	0	0	870	0	870
71	0	0	0	0	1	1	0	0	1	0	1	840	832	0	1	0	y	0	y
72	0	0	0	0	1	1	0	1	0	0	1	2,460	2,453	0	0	0	880	0	880
73	0	0	0	0	1	1	0	1	0	0	1	1,505	1,486	0	0	0	520	0	520
74	0	0	0	0	1	1	0	0	1	0	1	2,792	2,985	0	1	0			
75	1,282.9	15,141.4	17,321.2		3,007	457	149	15	1,890	250	2,152			291	1,516	69			

TABLE 1.—*(Continued)*

Line Number	Character of Oil Approx. Average during 1934			Character of Gas Approx. Average during 1934	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Gravity A.P.I. at 60° F. Weighted Average	Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
1	0	0	0	*y*	Cockfield	Eoc	Ss	Por	50	A	51	Mt. Selman	3,128
2	0	0	0	*y*	McElroy	Eoc	Ss	Por	20	A	14	Reklaw	5,000
3	*y*	0	*y*	0	Cockfield	Eoc	Ss	Por	*y*	*x*	*x*	*y*	*y*
4	19.5	*y*	*y*	*y*	Cockfield	Eoc	Ss	Por	13	*x*	*x*	Cook Mt.	2,860
5	16.0	*y*	*y*	0	McElroy	Eoc	Ss	Por	8	ML	30	Cockfield	3,000
6	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	15	ML	69	Cook Mt.	3,660
7													
8	0	0	0	*y*	Whitsett	Eoc	Ss	Por	35	AF	0	Mt. Selman	5,001
9	0	0	0	*y*	McElroy	Eoc	Ss	Por	10	AF	6	Mt. Selman	5,001
10	34.0	*y*	*y*	*y*	Cockfield	Eoc	Ss	Por	8	AF	10	Mt. Selman	5,001
11	46.0	*y*	*y*	*y*	Upper Saline Bayou	Eoc	Ss	Por	18	AF	17	Mt. Selman	5,001
12													
13	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	11	ML	95	Reklaw	5,000
14	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	11	MF	69	McElroy	2,400
15	18.0	*y*	*x*	0	McElroy	Eoc	Ss	Por	15	ML	15	Cockfield	2,791
16	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	9	MF	43	Cockfield	3,400
17													
18	22.5	*y*	2	*y*	Whitsett	Eoc	Ss	Por	8	AM	32	Reklaw	6,394
19	0	0	0	*y*	McElroy	Eoc	Ss	Por	10	A	27	Reklaw	6,394
20	22.5	*y*	2	0	McElroy	Eoc	Ss	Por	10	A	6	Reklaw	6,394
21	0	0	0	*y*	Cockfield	Eoc	Ss	Por	9	A	13	Reklaw	6,394
22	41.7	*y*	*y*	*y*	Upper Saline Bayou	Eoc	Ss	Por	14	A	13	Reklaw	6,394
23													
24	22.5	*y*	2	*y*	Whitsett	Eoc	Ss	Por	9	MF	28	Mt. Selman	5,222
25	52.0	*y*	*y*	0	Cockfield	Eoc	Ss	Por	20	Ds	26	Mt. Selman	4,502
26	22.5	*y*	2	*y*	Whitsett	Eoc	Ss	Por	7	MF	85	Mt. Selman	7,723
27	22.5	*y*	2	0	McElroy	Eoc	Ss	Por	6	ML	15	McElroy	2,500
28	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	17	MF	79	Lower Saline Bayou	4,942
29	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	11	ML	17	Mt. Selman	5,225
30	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	8	ML	24	Mt. Selman	4,532
31													
32	0	0	0	*y*	Whitsett	Eoc	Ss	Por	6	A	1	Caddell	3,448
33	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	6	A	0	Caddell	3,448
34	0	0	0	*y*	Caddell	Eoc	Ss	Por	10	A	1	Caddell	3,448
35	34.5	*y*	*y*	0	Caddell	Eoc	Ss	Por	61	A	0	Caddell	3,448
36													
37	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	19	MF	41	Mt. Selman	5,858
38	16.0	*y*	*y*	0	Cap Rock	*x*	L	Cav	5	Ds	66	Jackson	3,813
39	0	0	0	*y*	McElroy	Eoc	Ss	Por	10	*x*	20	Cockfield	3,000
40	35.2	*y*	*y*	*y*	Queen City	Eoc	Ss	Por	30	A	5	Reklaw	4,827
41													
42	0	0	0	*y*	McElroy	Eoc	Ss	Por	12	ML	0	Cockfield	3,500
43	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	16	ML	15	Cockfield	3,500
44	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	7	ML	29	Cockfield	3,500
45													
46	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	7	MF	6	McElroy	2,400
47	18.0	*y*	*y*	*y*	Frio	Olig	Ss	Por	11	ML	65	McElroy	2,500
48	0	0	0	*y*	Whitsett	Eoc	Ss	Por	10	*x*	2	McElroy	2,000
49	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	40	MF	14	McElroy	2,800
50	27.3	*y*	*y*	*y*	Frio	Olig	Ss	Por	8	*x*	17	McElroy	2,429
51	22.0	*y*	*y*	0	Cockfield	Eoc	Ss	Por	19	*x*	18	Cockfield	1,085
52	48.5	*y*	*y*	*y*	Cockfield	Eoc	Ss	Por	9	MF	29	Mt. Selman	3,225
53	0	0	0	0	McElroy	Eoc	Ss	Por	20	*x*	0	Cook Mt.	3,000
54	0	0	0	0	McElroy	Eoc	Ss	Por	16	*x*	5	McElroy	3,210
55	0	0	0	0	Frio	Olig	Ss	Por	21	*x*	2	Caddell	3,600
56													
57	0	0	0	0	Whitsett	Eoc	Ss	Por	3	MF	15	Cockfield	3,307
58	0	0	0	0	McElroy	Eoc	Ss	Por	14	MF	13	Cockfield	3,307
59													
60	22.5	*y*	2	0	McElroy	Eoc	Ss	Por	11	AF	6	Upper Saline Bayou	2,178
61	0	0	0	*y*	McElroy	Eoc	Ss	Por	10	*x*	6	McElroy	3,000
62	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	11	*x*	3	Caddell	3,102
63	35.2	*y*	*y*	*y*	McElroy	Eoc	Ss	Por	22	MF	13	Cockfield	3,600
64	0	0	0	*y*	McElroy	Eoc	Ss	Por	6	*x*	3	Cockfield	3,512
65	27.7	*y*	*y*	*y*	Frio	Olig	Ss	Por	15	*x*	6	McElroy	3,610
66													
67	22.5	*y*	2	*y*	Whitsett	Eoc	Ss	Por	10	MF	6	McElroy	2,364
68	22.5	*y*	2	*y*	McElroy	Eoc	Ss	Por	10	MF	5	McElroy	2,364
69													
70	0	0	0	*y*	Queen City	Eoc	Ss	Por	55	A	0	Queen City	2,180
71	22.5	*y*	2	0	McElroy	Eoc	Ss	Por	8	*x*	1	Cockfield	2,500
72	0	0	0	*y*	McElroy	Eoc	Ss	Por	7	*x*	0	McElroy	2,460
73	0	0	0	*y*	Whitsett	Eoc	Ss	Por	19	*x*	0	McElroy	3,000
74	24.5	*y*	2	0	McElroy	Eoc	Ss	Por	7	*x*	0	McElroy	2,792
75													

TABLE 2.—*Summary of Drilling Operations in Southwest Texas*
(Figures in body of tabulation represent number of holes.)

County	Completed during 1934[1]									Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes								Productive Wells		
	Total Depths, Ft.							Total	(For Details See Table 1)	Within Fields	Exploratory
	0–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000				
Dimmitt	0	0	0	0	0	0	0	0	0	0	0
Duval	0	2	12	7	0	3	1	25	331	21	10
Jin Hogg	0	0	4	4	2	0	0	10	0	4	0
LaSalle	0	0	2	0	0	0	0	2	0	0	0
McMullen	5	4	14	2	1	0	0	26	30	5	5
Starr	3	4	7	2	0	1	0	17	34	4	10
Webb	0	2	1	3	1	0	0	7	33	13	3
Zapata	1	7	5	1	0	0	0	14	30	6	5
Total	9	19	45	19	4	4	1	101	458	53	33

[1] Includes only those outside of fields.

Development and Production in West Texas, 1934

By H. B. Fuqua* and B. E. Thompson*

(New York Meeting, February, 1935)

The area discussed in this paper, commonly known as the West Texas district, is easily divisible into three geologic provinces, the Midland Basin to the east, the Delaware Basin to the west and the West Texas structural platform separating these two. Production in Garza, Scurry, Mitchell, Howard, Glasscock, Irion, Reagan and central Crockett counties is associated with the east flank of the Midland Basin. That in Loving and Reeves counties is associated with the Delaware Basin. All other production and developments discussed in this paper belong to the province of the West Texas structural platform.

Because of certain developments that have occurred during the past year, it has been found necessary to slightly revise one of the fields as grouped by Mr. Reith in last year's paper[1]. The Scarborough-Leck field has been broken down as follows (Table 1): The Leck field is shown separately because it is producing from dolomite; while the Scarborough area, producing from sand, is regrouped and designated as "Scarborough-Kermit-Halley," which includes the producing sand belt across Winkler County from Ward County to New Mexico. It is believed that this is a more logical division of Winkler County and that considerable future work will be avoided by making this change before further production figures have accumulated under the present set-up. A number of new fields are listed in Table 1, some of which may represent extensions of other producing areas. The authors, however, are inclined to believe that they represent new fields. In either event, less work is involved in adding two areas together, if they later prove to be one, than in attempting to separate a maze of production data into two fields after they have been erroneously carried as one for a number of years. The Howard-Glasscock field is designated in this review as the Chalk-Roberts field and the Denman production on the Howard-Mitchell County line is included in the Iatan field.

DEVELOPMENT DURING 1934

Development in West Texas during the year 1934 showed a marked increase over the previous year both in exploration and in exploitation

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[1] *Trans.* A.I.M.E. (1934) **107,** 339.

of proven or semiproven areas, as evidenced by the fact that 468 wells were drilled as compared to 236 wells during 1933. At least nine wells that can be classed as real wildcats were completed as producers during the year. Of these, two were in Andrews County, three in Ector County, two in Winkler County and two in Pecos County.

The Humble Oil and Refining Co. No. 1 R. M. Means in north central Andrews County was completed at 4527 ft. in December, 1934, with an initial daily production of 587 bbl. flowing. The Honolulu & Llano No. 1 Parker, near the town of Andrews, was completed at 4780 ft. in December, 1934, with an initial daily production of 153 bbl., pumping. Both of these wells appear to open new pools, although it is impossible to hazard

TABLE 1.—*Oil and Gas Production in West Texas*

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres			
			Oil	Oil and Gas[a]	Gas	Total
1	Toyah, *Reeves*	15	640	0	0	640
2	Westbrook, *Mitchell*	14	4,000			4,000
	Big Lake, *Reagan*					
3	2,400-ft. pay[1]	11	*y*	*y*	*y*	*y*
4	3,000-ft. pay[1]	11	3,000			3,000
5	Ordovician	6	1,200			1,200
6	Emerald, *Garza*	10	320			320
7	Ira, *Scurry*	10	640			640
8	Church-Fields-McElroy, *Crane, Upton*	9	13,500	0	0	13,500
	Chalk-Roberts, *Howard, Glasscock*					
9	1,400-ft. pay	8	700		0	700
10	1,700-ft. pay	9	5,000	0	0	5,000
11	2,200-ft. pay	6	4,400	*x*	0	4,400
12	2,500-ft. pay	7	1,000	0	0	1,000
13	3,000-ft. pay	7	3,200	0	0	3,200
14	Iatan-Denman, *Mitchell, Howard*	9	6,500	0	0	6,500
15	McCamey, *Upton, Crane*	9	10,000			10,000
16	Wheat, *Loving*	9	4,500			4,500
17	World-Powell-Grayson, *Crockett, Reagan*	9	2,500	0	0	2,500
	Yates, *Pecos, Crockett*					
18	Lime	8	17,000	0	0	17,000
19	Sand	1	700			700
20	Toborg	5	1,000	0	0	1,000
21	Hendrick, *Winkler*	8	9,200	6,000	0	9,200
22	Penn, *Ector*	8	4,000	40		4,000
23	Leck, *Winkler*	7	500	0	0	500
24	Scarborough-Kermit-Halley, *Winkler*	7	5,000	5,000		5,000
25	Waddell, *Crane*	7	3,000		1,000	4,000
26	Pecos Valley, *Pecos*	6	1,500	0	80	1,580
27	Pryor, *Pecos*	6	160			160
	Taylor-Link, *Pecos*					
28	Lime	6	1,000			1,000
29	Sand	5	450			450
30	Ward Co., *Ward*	6	20,000	15,000	1,000	21,000
31	Irion Co., *Irion*	5	340	0	0	340
32	Masterson, *Pecos*	5	160			160
33	Deep Rock-Fuhrman, *Andrews*	4	3,000			3,000
34	Cowden, *Ector*	4	4,000		0	4,000
35	Sand Hills, *Crane*	4	160		0	160
36	Todd Ranch, *Crockett*	3	320		160	480
37	Addis, *Ector*	2	1,500		40	1,540
38	Harper, *Ector*	1	160		0	160
39	Davidson, *Ector*	0	160	160		160
40	Means, *Andrews*	0	880	480	0	880
41	Landreth-Scarborough, *Ector*	0	160	160		160
42	White-Baker, *Pecos*	0	320	0	0	320
43	Parker, *Andrews*	0	160	0	0	160
44	Landreth-Johnson, *Ector*	0	160	0	0	160
45	Total		133,040	26,840	2,280	135,320

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[1] Production from 2,400-ft. pay in 10 wells, now deepened to 3,000-ft. pay, is reported with 3,000-ft. pay for 1933.

even a guess as to the extent of either. The Humble also completed its No. 1 Walker as a small producer. This well lies between the Ogden pool to the north and the Fuhrman producers to the south, and indicates that production will be continuous here.

The Davidson et al. No. 1 H. E. Cummins in northwest Ector County was completed in August, 1934, at 4509 ft., with an initial daily production of 25 bbl. with considerable gas. About 10 miles to the southeast, the Landreth Production Co. No. 1 Scharbauer was temporarily shut down at a depth of 4186 ft. This well showed as much as 30 million cubic feet of gas and sprayed about 40 bbl. of oil daily. However, the well has never been satisfactorily completed. Additional development

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells		
	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	During 1934 Completed	During 1934 Abandoned
1	6,400	250	400	2	100	100	*y*					35	0	*y*
2	7,443,093	378,336	467,285	960	1,860	371	7					136	0	2
3	2,099,313	144,434	93,094	250	*y*	*y*	35	*x*	*x*	*x*	*x*	21	0	3
4	55,053,870	2,253,807	1,592,719	4,000	18,351	612	28	*x*	*x*	*x*	*x*	261	0	2
5	22,673,728	4,206,016	2,402,237	6,833	18,895	*x*	*x*	*y*	*y*	*y*	*y*	23	2	0
6	33,757	7,876	5,322	15	100	10	3					7	0	0
7	108,771	9,322	10,221	24	170	7	3					7	1	1
8	91,848,128	4,646,597	4,500,160	9,105	6,800	91	87	62,818	3,026	3,724		347	4	0
9	2,895,000	321,418	240,000	590	4,135	*x*	12					51	0	0
10	9,553,404	825,532	798,952	2,166	1,910	95	8					266	6	0
11	22,785,351	2,953,733	3,061,535	7,640	5,178	*x*	48					160	40	0
12	4,850,905	527,147	474,672	1,326	4,850	*x*	32					41	1	0
13	18,507,592	931,573	893,636	2,200	5,783	*x*	29					146	0	0
14	2,697,112	236,479	695,278	1,164	4,145	83	26					67	45	0
15	26,501,617	1,483,563	1,553,661	5,038	2,687	90	17	*x*	*x*	*x*	*x*	393	17	53
16	5,081,726	926,746	802,144	2,086	1,130	162	29	*x*	*x*	*x*	*x*	84	10	6
17	4,575,559	340,576	302,531	838	1,830	141	20	*x*	*x*	*x*	*x*	60	0	0
18	195,688,692	20,228,277	15,409,209	36,876	11,500	192	80	105,412	6,838	4,741	17	456	32	0
19	58,814	4,255	54,559	163			41	*x*	*x*	*x*	*x*	4	1	0
20	2,434,195	459,124	422,504	1,150	2,434	122	13	*x*	*x*	*x*	*x*	89	13	
21	173,637,211	7,355,964	6,356,359	17,000	18,870	*x*	53	*x*	*x*	*x*	*x*	625	0	10
22	10,934,757	1,727,392	2,028,542	4,890	2,720	68	51	10,542	1,771	2,823	*y*	97	14	0
23	2,759,995	227,809	196,273	534	*x*	*x*	45	*x*	*x*	*x*	*x*	16	0	0
24	2,189,576	490,726	839,968	3,122			37	*x*	*x*	*x*	*x*	90	44	0
25	40,868	0	1,736	17			17	*x*	*x*	18	*x*	7	2	1
26	370,365	79,708	43,742	121	248	17	4	*x*	*x*	*x*	*x*	37	2	*y*
27	22,505	7,475	1,490	0	140	25	0	*x*	*x*	*x*	*x*	3	0	2
28	2,995,837	186,145	361,644	990	2,996	200	21	*x*	*x*	*x*	*x*	48	1	1
29	435,791	33,833	18,270	50	970	160	6	*x*	*x*	*x*	*x*	8	0	0
30	10,688,121	2,661,936	3,551,902	12,297	500	10	35	*x*	*x*	*x*	*x*	353	124	0
31	70,542	8,127	10,096	40	203	20	5	*x*	*x*	*x*	*x*	14	2	4
32	21,196	2,838	10,916	53	132	27	17	*x*	*x*	*x*	*x*	6	1	0
33	219,234	14,060	155,333	486	73		61	*x*	*x*	*x*	*x*	9	2	0
34	548,583	114,165	388,152	1,341	137	5	43	*x*	*x*	*x*	*x*	31	24	0
35	37,653	6,089	10,691	15			15	*x*	*x*	*x*	*x*	1	0	0
36	10,718		10,718	13			6	*x*	*x*	*x*	*x*	6	0	0
37	307,878	109,987	190,034	571	226	23	44	*x*	*x*	*x*	*x*	13	7	0
38	31,381	6,585	24,796	61			61	*x*	*x*	*x*	*x*	1	0	0
39	0	0	0	0				*x*	*x*	*x*	*x*	1	1	0
40	22,193		22,193	119	184		49	150		150	1.5	3	3	0
41	0	0	0	0				*x*	*x*	*x*	*x*	1	1	0
42	0	0	0	0								2	1	0
43	0	0	0	0								1	1	0
44	0	0	0	0								1	1	0
45	680,241,431	53,917,900	48,002,974	124,146								4,028	403	85

[b] Footnotes to column headings and explanation of symbols are on page 249.

is now being carried on in both areas and the value of these discoveries cannot be determined for some time. Landreth Production Co. also completed a wildcat test on the Johnson ranch, 3 miles south of the Cowden pool, in December, 1934. This may or may not represent an extension to that pool. It is capable of producing about 100 bbl. daily.

During the latter part of 1934, the Sayre Oil Co. No. 1 Howe, near Kermit, Winkler County, and the Skelly Oil Co. No. 1 Halley, near the center of the south line of the county, were completed as nice wells, averaging about 400 bbl. daily each at depths approximating 3000 ft. These wells are producing from the O'Brien sand section, and suggest strongly that this production will extend continuously across both Ward and Winkler coun-

TABLE 1.—(*Continued*)

	Number of Oil and/or Gas Wells					Average Depth, Ft.		Oil Production Methods at End of 1934			Pressure, Lb. per Sq. In.^{e}			Character of Oil Approx. Average during 1934				
	At End of 1934							Number of Wells				Average at End of		Gravity A.P.I. at 60° F.				
Line Number	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas^c	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Initial	1933	1934	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base^f
1	*y*	10±			10±	100	100	0	*y*	0	*x*	*x*	*x*			27	1.7	M
2	20	97			97	3,000	2,800	0	97	0	1,000	*y*	*y*	27	25	26	2.5	M, A
3	0	7	0	0	7	2,500	2,375	0	7	0	*x*	*x*	*x*			35	*y*	*y*
4	0	145	0	0	145	3,000	2,970	0	145		*x*	*x*	*x*			36	0.4	M
5	0	23		0	23	8,700	8,300	23	0		3,750	*y*	*y*	58	42	46	0.2	P
6	1	5	0	0	5	2,600	2,510	0	5	0	*x*	*x*	*x*	40	38	39	*y*	*y*
7	0	5	0	0	5	2,395	2,325	0	5	0	*x*	*x*	*x*	25	25	25	2.1	M
8	27	314		0	314	3,000	2,800	46	267	1	725	538	*y*	33	30	32	2.5	M
9	0	51	0	0	51	1,400	1,280	0	51	0	*x*	*x*	*x*			33	1.0	*y*
10	0	260	0	0	260	1,750	1,650	0	260	0	*x*	*x*	*x*			32	0.8	*y*
11	0	160	0	0	160	2,300	2,150	0	160	0	*x*	*x*	*x*			30	1.6	*y*
12	0	41	0	0	41	2,600	2,500	0	41	0	*x*	*x*	*x*			27	3.4	*y*
13	0	76	0	0	76	3,000	2,900	0	76	0	*x*	*x*	*x*			27	2.0	*y*
14	*y*	93	0	0	67	2,800	2,400	0	93	0	*x*	*x*	*x*	32	30	31	2.0	M
15	*y*	306	0	0	306	2,600	2,000	6	300	*x*	*x*	*x*	*x*			28	2.0	M
16	0	73		0	73	4,304	4,297	69	4	0	1,650	1,500	1,300	39	37	38	0.2	P, M
17	0	41	0	0	41	2,660	2,645	0	41	0	*x*	*x*	*x*	30	28	29	0.7	M, A
18	0	456	0	0	456	1,450	1,310	440±	16±	0	700	547	533	31	29	30	1.6	M
19	0	4		0	4	1,100	900	0	4	0	*y*	*y*	*y*	*y*	*y*	32	*y*	M
20		89		0	89	445	400	0	89	0	*x*	*x*	*x*	*y*	*y*	23	1.9	M
21	54	449		6	455	2,900	2,600	237	210	2	1,600±	*x*	*x*	35	24	28	1.5	M
22	1	95	0	1	96	3,700	3,550	85	10	0	1,500±	923		35	32	33	2.6	M
23	0	12	0	0	12	3,100	3,000	*y*	*y*	0	1,600±	*x*	*x*			28	1.5	M
24	0	85		5	90	3,300	2,800	78	7	0	1,400±	*y*	*y*	38	34	36	1.2	P, M
25	4	1	0	1	2	3,400	3,200	0	1	0	1,500±			33	32	33	1.8	M
26	7	19		2	21	1,600	1,300	*y*	*y*	0	*x*	*x*	*x*			30	1.0	M
27	0	0	0	0	0	1,400	1,385	0	0	0	*x*	*x*	*x*	24	24	24	0.6	A
28	0	47	0	0	47	1,675	1,630	1	46	0	*x*	*x*	*x*	31	29	30	1.3	M
29	0	8	0	0	8	1,000	970	0	8		*x*	*x*	*x*	28	28	28	*y*	*y*
30	0	349	0	4	353	2,800	2,500	300±	49±	0	1,400	1,250	1,100±	38	31	36	1.2	P, M
31		8	0	0	8	1,410	1,400	0	8	0	*x*	*x*	*x*			40	*y*	*y*
32	3	3	0	0	3	1,400	1,200	*y*	*y*	0	*x*	*x*	*x*			28	*y*	M
33	1	8		0	8	4,500	4,300	*y*	*y*	0	*x*	*x*	*x*	26	26	26	*y*	M
34	0	31		0	31	4,300	4,200	29	5		1,640	1,627	1,575	34	30	32	1.7	M
35	0	1		0	1	4,440	4,300	1	0	0	1,200+	*x*	*x*	37	37	37	0.7	M
36	4	2		0	2	2,600	1,200	0	2	0	*x*	*x*	*x*	*y*	*y*	*y*	*y*	M
37	1	12			12	4,100	3,900	10	2	0	1,485	1,480	1,200	34	30	32	*y*	*y*
38	0	1		0	1	4,338	4,147	0	1	0	*x*	*x*	*x*			37	*y*	*y*
39	1	0		0	0	4,500	4,300	1	0	0	*y*	*y*	*y*	29	29	29	*y*	*y*
40	0	1	2	0	3	4,539	4,500	2	1	0	*x*		*x*	31	31	31	*x*	P
41	1	0	0	0	0	4,200	4,000	1	0	0	*y*	*y*	*y*	33	33	33	*y*	*y*
42	1	1	0	0	1	1,810	1,808	1	0	0	700		700	31	31	31	*y*	*y*
43	0	1	0	0	1	4,750	4,600	0	1	0				33	33	33	*y*	*y*
44	0	1	0	0	1	4,180	4,080	1	0	0				29	29	29	*y*	*y*
45		3,391±	2	19	3.386±			891±	1,996±	3								

ties. In Pecos County, the Tex-Mex Production Co. developed a small producer south of Grand Falls, which lies across the Pecos River in Ward County. This well probably represents a southward extension of the Ward County producing area. The producing depth is 2291 ft. In December, 1934, the Gulf Production Co. developed a 30-bbl. well on its White-Baker block, about one mile north of the Humble Oil and Refining Company's deep (9811 ft.) failure on the same ranch. Additional development will be necessary in order to determine the value of this discovery, which lies midway between the Taylor-Link and Yates fields.

Most of the discoveries discussed above appear to be very light wells but this does not necessarily mean that the fields will be of negligible importance. The discovery well of Church-Fields-McElroy produced

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1934		Producing Rock					Structure[j]	Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	B.t.u. per Cu. Ft.	Gals. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average, Ft.			Name	Depth of Hole, Ft.
1				Pli?	SH	Por	1	MC	*y*	Delaware Mt.	4,133
2			Big Lime	Per	D, L	Por	50	MC	3	Pennsylvanian	5,250
3	*y*	*y*		Per	S	20	*x*	A, D			
4	*y*	4.0	Big Lake Ls	Per	D, L	Por, Cav	30	A, D	0		
5	1,200	0.9	Ellenburger	Ord	L	Cav		D	1	Lower Ordovician	9,562
6			Big Lime	Per	S, LS	Por	10	A	1	Permian	4,801
7			Big Lime	Per	D, L	Por	25	MC	7	Permian	4,528
8	1,110	1.7	Big Lake Ls	Per	D, L	15	75	A	3	Ordovician	10,978
9			1,400-ft. sand	Per	S	Por	*x*	A		Permian	4,393
10			1,700-ft. sand	Per	S	22	20	A	3		
11			2,200-ft. pay	Per	D, L	Por	*x*	A	7		
12			2,500-ft. pay	Per	D, L	Por	*x*	A	2		
13			3,000-ft. pay	Per	D, L	Por	*x*	A	13		
14			Big Lime	Per	D, L	Por	50	A	9	Permian	4,220
15			Big Lake Ls	Per	D, L	Cav	30	A	37	Permian	4,610
16	1,000	1.0	Delaware sand	Per	S	Por	7	M	4	Permian	5,083
17			Big Lake Ls	Per	D, L	Por	13	A, D	4	Ordovician	8,830
18	*y*	1.0	Yates Ls	Per	D, LS	Por, Cav	60	A	0	Permian	1,883
19	*y*	*y*	Yates sand	Per	S	Por	15	AL			
20			Toborg sand	Cre?	S, D	Por	20	AL	14		
21	*y*	*y*	Big Lime	Per	D	Por, Cav	*x*	A	26	Permian	3,962
22	*y*	1.5	Big Lake Ls	Per	D	Por	40	A	3	Permian	4,002
23	*x*	*x*	Big Lime	Per	D	Por, Cav	*x*	D	5	Permian	3,780
24	1,100	1.0	O'Brien sand	Per	S, D	Por	40	M	4	Permian	4,639
25	*y*	0.5	Big Lake Ls	Per	S, D	Por	15	A	2	Permian	3,859
26	1,000	*y*	Pecos Valley sand	Per	S, D	Por	15	M	8	Permian	2,389
27				Per	SH	Por	5	A	0	Permian	4,375
28			Big Lime	Per	D, L	Por, Cav	15	D	0	Permian	2,185
29			Yates sand	Per	S	Por	6	D	1		
30	1,129	1.2	O'Brien sand	Per	S, D	Por	50	M, L	12	Permian	4,825
31	*y*	*y*		Per	S	Por	10	M	16	Permian	3,511
32	*y*	*y*	Pecos Valley sand	Per	S	Por	5	M	5	Permian	1,675
33	*y*	*y*	Big Lake Ls	Per	D, S	Por	25	A	3	Permian	4,700
34	*y*	0.5	Big Lake Ls	Per	D, S	19.1	30	A	0	Permian	4,627
35	*y*	*y*	Big Lime	Per	D, L	Por	10	A	1	Permian	5,336
36	*x*	*x*	Big Lime	Per	D	Por	10	A	0	Ordovician	8,041
37	*y*	0.5	Big Lake Ls	Per	D, S	16.5	10	D, A	2	Permian	4,702
38	*y*	*y*	Big Lake Ls	Per	D, S	Por	10	A	0	Permian	4,338
39	*y*	*y*	Big Lake Ls	Per	D	Por	30	A	0	Permian	4,509
40	*y*	*y*	Big Lake Ls	Per	D	17	25	A	0	Permian	4,539
41	*y*	*y*	Big Lake Ls	Per	D	Por	30	A	0	Permian	4,190
42				Per	D	Por	2	M	1	Ordovician	9,811
43			Big Lake Ls	Per	D	Por	30	A	0	Permian	4,780
44			Big Lake Ls	Per	D, S	Por	30	A	0	Permian	4,180
45											

TABLE 2.—*Summary of Drilling Operations in West Texas*
(Figures in body of tabulation represent number of holes.)

County	Completed Prior to January 1, 1935												Completed during 1934									Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes											Productive Wells (For Details See Table 1)	Dry and/or Near-dry Holes								Productive Wells (For Details See Table 1)		
	Total Depths, Ft.										Total		Total Depths, Ft.							Total			
	0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000	8,000–9,000	9,000–10,000			0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	9,000–10,000			Within Fields	Exploratory
Andrews	0	0	0	1	9	3	0	0	0	0	13	13	0	0	0	0	0	1	0	1	6	2	2
Bailey	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Borden	2	4	2	15	2	0	0	0	0	0	25	0	0	0	0	1	0	0	0	1	0	0	0
Brewster	0	8	7	6	2	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	3
Cochran	0	2	0	0	0	4	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	1
Cottle	1	0	1	2	4	1	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0
Crane	1	1	6	21	8	0	0	0	0	0	37	330	1	0	0	1	2	0	0	4	5	2	5
Crockett	1	24	28	28	7	1	1	0	1	0	91	71	0	2	0	0	0	0	0	2	0	0	2
Crosby	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Culberson	13	3	3	11	1	1	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0	0	3
Dawson	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1
Dickens	0	0	2	2	1	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Ector	0	2	1	11	17	0	0	0	0	0	31	145	0	0	0	1	6	0	0	7	48	16	0
ElPaso	0	0	0	3	0	0	0	0	0	0	3	0	0	0	0	1	0	0	0	1	0	0	1
Floyd	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Gaines	0	0	0	4	5	0	0	0	0	0	9	0	0	0	0	0	1	0	0	1	0	0	0
Garza	1	0	8	10	2	1	0	0	0	0	22	7	0	0	0	0	0	0	0	0	0	0	0
Glasscock	0	3	19	36	2	0	0	0	0	0	60	130	0	1	3	2	0	0	0	6	42	8	3
Hale	6	1	0	1	1	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0
Hockley	0	2	0	1	1	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Howard	2	7	5	31	5	0	0	0	0	0	50	585	0	1	0	2	0	0	0	3	48	29	2
Hudspeth	2	6	2	1	1	0	0	0	0	0	12	0	0	1	0	0	0	0	0	1	0	0	0
Irion	5	36	7	9	0	0	0	2	2	0	61	14	0	4	0	0	0	0	0	4	2	1	0
Jeff Davis	1	1	1	3	1	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	1
Kent	2	0	1	4	2	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0
King	1	1	0	8	2	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0
Lamb	0	1	0	0	2	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0
Loving	2	0	0	2	11	3	0	0	0	0	18	84	0	0	0	0	1	0	0	1	10	4	0
Lubbock	2	0	0	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Lynn	1	1	1	1	0	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	1
Martin	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1
Midland	0	0	1	1	7	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0
Mitchell	13	5	4	43	3	1	0	0	0	0	69	152	0	0	0	0	0	0	0	0	2	0	2
Motley	2	0	1	2	5	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0
Pecos	17	120	77	30	9	1	0	0	0	1	255	644	3	5	2	0	0	0	1	11	51	14	2
Presidio	4	1	0	2	1	1	0	0	0	0	9	0	1	0	0	0	0	0	0	1	0	0	1
Reagan	0	1	12	49	1	0	0	0	0	0	63	309	0	0	1	1	0	0	0	2	2	2	1
Reeves	6	8	4	13	10	3	0	0	0	0	44	35	0	0	0	1	0	1	0	2	0	0	1
Schleicher	2	0	0	3	0	2	3	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	3
Scurry	6	2	2	12	5	1	0	0	0	0	28	7	1	0	1	1	0	0	0	3	1	0	2
Sterling	4	9	5	19	1	0	0	0	0	0	38	0	0	1	1	0	0	0	0	2	0	0	1
Stonewall	0	2	1	6	1	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	1
Sutton	2	2	0	1	4	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	1
Terrell	5	0	3	5	2	2	0	0	0	0	17	0	1	0	0	0	0	0	0	1	0	0	1
Terry	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Tom Green	25	19	4	11	1	0	0	0	0	0	60	0	2	0	0	1	0	0	0	3	0	0	0
Upton	1	1	28	24	5	0	0	0	0	0	60	418	0	0	0	0	1	0	0	1	18	9	0
Val Verde	1	0	7	8	2	0	2	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0
Ward	8	1	36	14	4	3	0	0	0	0	66	353	1	0	1	3	1	1	0	7	124	44	1
Winkler	1	0	3	24	4	0	0	0	0	0	32	731	0	0	0	0	0	0	0	0	44	17	4
Yoakum	2	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Total	142	274	284	480	157	32	6	2	3	1	1,382	4,028	10	15	9	15	12	3	1	65	403	148	47

only 30 bbl. daily, and the prolific Hendrick pool of Winkler County was discovered by a west edge well capable of producing only 125 bbl. per day.

In addition to the exploratory drilling, a great deal of inside and extension drilling took place. The Ward-Winkler County sand area led by a wide margin in this work, with a total of 168 producers completed. Important extensions were developed at various points along the trend. The Penn field of Ector County was extended to the north and west; while the Cowden area continued to develop southward. Because of the awarding of additional vacancy claims, the drilling campaign started during the last half of 1933 still continues in the Yates field of Pecos County. Considerable drilling to both the sand and dolomite horizons took place in the Chalk-Roberts field and the portion of the Iatan field located in Howard County was very active.

Prospecting for horizons deeper than Permian continued throughout the year. The Humble Oil and Refining Company's No. 1 White-Baker, in Pecos County, was abandoned at 9811 ft. in Ellenburger limestone. Their No. 1 Ike Honig, 10 miles northeast of Eldorado in Schleicher County, was abandoned in Ellenburger limestone at a depth of 6472 ft. Also, this company has recently spudded two additional deep tests, one in northeast Upton County and one in central Crockett County. The Gulf Production Company's No. 103 J. T. McElroy, in the Church-Fields-McElroy pool on the Upton-Crane County line, was drilling on Dec. 31, 1934, at 10,978 ft. in pre-Pennsylvanian rocks, having encountered slight showings of oil near its total depth. Since that date, the well has passed the 11,000-ft. mark. The Gulf Company has also spudded a deep test in the Sand Hills area of western Crane County. The Moore et al. No. 1 L. S. McDowell et al. in north central Glasscock County is drilling at a depth of 8269 ft. in Pennsylvanian sediments. The Skelly Oil Co. No. 1 University "D," midway between the Big Lake and World-Powell fields, has drilled to a depth of 8830 ft. without encountering the deep producing horizon of Big Lake.

Drilling Methods and Acid Treatment

The cable-tool method of drilling, on the whole, has proved to be most satisfactory in West Texas, although in areas where special conditions have been found considerable rotary work is being done. Rotary drilling predominates in Andrews and northern Ector counties, is used considerably in the Chalk-Roberts field and almost exclusively along the west edge of production in Ward County. In all of these areas the upper red bed section is considerably thicker than the average for West Texas and makes cable-tool operation slow and expensive. In addition, high pressures and large volumes of gas are encountered in Ward County, making drilling in with cable tools very dangerous, unless loading of the hole is resorted to, which causes watering or mudding of the sands similar to that resulting from drilling in with rotary. This danger is being overcome by employing the pressure method of rotary drilling while penetrating the producing horizons. Under this system the dangers associated with cable-tool drilling are eliminated, while a minimum of damage is done to the pay section. The disadvantage of the method is that it can be used only where a large volume of high-pressure surplus gas is available at small cost. A number of operators in West Texas drill with rotary to the point where the oil string is set, then complete the well with cable tools.

The treatment of wells with hydrochloric acid solution has been continued throughout the year 1934 with varying degrees of success. The treatment proved to be very successful in the Chalk-Roberts and McCamey fields, while in practically all other areas it appears to have more than justified its use. Some increase in flush production was secured by treating new wells in Andrews and Ector counties, but by far the most important use of this method seems to be the reviving of old semidepleted limestone or dolomite pays that are approaching the point of economic exhaustion.

Outlook for 1935

The outlook for the year 1935 in West Texas appears most favorable. Many operators who deserted the area several years ago for the apparently more fruitful field to the east have returned or are returning to the land of slightly sulfurous but highly prolific oil fields. Wildcatting, both by major and independent operators, is decidedly on the increase, and desirable acreage is changing hands at rising prices. Development of proven and semiproven properties, which has been postponed during the past few years, is gradually returning to normal and hundreds of wells that have been in need of reconditioning for some time are being cleaned out, shot, acid-treated or otherwise put into shape. The general feeling in the field is one of optimism and it appears probable that the coming year will see the proving up of several embryo fields discovered during 1934, as well as the successful testing of additional wildcat prospects.

Acknowledgments

The writers gratefully acknowledge the information and assistance given by C. B. Carpenter in compiling data on the difficult Chalk-Roberts field and by C. W. Reith in preparing data on the separate pays in the Taylor-Link field of Pecos County. Messrs. J. B. Lovejoy, G. L. Klingaman, H. M. Bayer, B. G. Martin, J. Ben Carsey and many others assisted in various ways in the accumulation and compilation of the mass of data employed.

Oil and Gas Development in Utah, 1934

By H. W. C. Prommel*, Member A.I.M.E.

(New York Meeting, February, 1935)

While Utah remains an unimportant factor in oil production, exploratory drilling was carried on in six widely separated areas, extending from the southwest to the northeast corner of the state. One new gas field, the Last Chance or Starvation Creek anticline in Emery County, and two new gas horizons in the Clay Basin field of Daggett County, were thereby discovered during 1934.

Exploratory Drilling

South Central Utah

Emery County—Last Chance Anticline.—The test of the Ramsey Petroleum Corporation in sec. 18, T.26S., R.7E., on the apex of this anticline (vert. closure 700 ft.; area within closing contour line, as mapped by U.S. Geological Survey, 26,000 acres) encountered gas in the Moenkopi formation of lower Triassic age at depths ranging from 2530 to 2863 ft. The total thickness of sandstone, sandy shale and limestone beds in which gas was encountered is approximately 50 ft. The well was tested at a depth of 2755 ft., gaging 21,000,000 cu. ft. of gas, R.P. 410 lb. The well is being plugged back to the lowest gas horizon at 2771 ft. from a total depth of 3168 ft. Gas from this well probably will be used for the drilling of a second well structurally lower, to test the oil possibilities of the Moenkopi formation as well as of the upper and lower Pennsylvanian formations, of which the latter so far remains untested in South Central Utah. The well was not drilled deep enough to determine more definitely the western margin of the petroliferous Paradox Basin of lower Pennsylvanian age of southeastern Utah.

Woodside Anticline.—This field, lying immediately northeast of the San Rafael swell, contains, according to maps of the U.S. Geological Survey, 8380 acres within its lowest closing contour line 700 ft. below the apex. A well was drilled by Utah Oil Refining Co. at the apex in sec. 12, T.19S., R.13E., during 1924. Gas was encountered in the Moenkopi and Kaibab formations of Triassic and Carboniferous (Permian) age respectively. The flow is estimated at 21,000,000 cu. ft., R.P. 900 lb.,

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TABLE 1.—*Oil and Gas Production in Utah*

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres: Oil	Area Proved, Acres: Gas	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1934	Total Oil Production, Bbl.: During 1933	Total Oil Production, Bbl.: During 1934	Total Oil Production, Bbl.: Daily Average during Nov., 1934	Average Oil Production, Bbl.: Per Acre to End of 1934[b]	Average Oil Production, Bbl.: Per Acre-foot to End of 1934	Average Oil Production, Bbl.: Per Well Daily during Nov., 1934
1	Virgin, *Washington*........	27	450	0	450	150,000	4,500	3,500	9.6	333	225	0.5
2	San Juan, *San Juan*.......	25	160	0	160	11,*xxx*	6*xx*	1*xx*	0.5	*x*	*x*	*x*
3	Farnham, *Carbon*..........	11[5]	0	600	600	0	0	0	0	0	0	0
4	Cisco, *Grand*..............	10[6]	0	4,000	4,000	0	0	0	0	0	0	0
5	Ashley Valley, *Uintah*.....	9[8]	0	335	335	0	0	0	0	0	0	0
6	Totals.................		610	6,935	7,545	161,*xxx*	5,1*xx*	3,600	10.1			

Line Number	Total Gas Production, Millions Cu. Ft.: To End of 1934	Total Gas Production: During 1933	Total Gas Production: During 1934	Total Gas Production: Maximum Daily during 1934	Number of Oil and/or Gas Wells: Completed to End of 1934	During 1934: Completed	During 1934: Abandoned	At End of 1934: Temporarily Shut Down	At End of 1934: Producing Oil Only	At End of 1934: Producing Gas Only	At End of 1934: Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1934, Number of Wells: Pumping	Oil Production Methods at End of 1934, Number of Wells: Miscellaneous
1	0	0	0	0	50	1	0	17	9	0	9	665[1]	665[1]	8	1[4]
2	0	0	0	0	9	1	1	8[2]	1	0	1	200	194	1	0
3	121.3	23.2	38.4	0.2	2	0	0	0	0	1	1	3,114	3,093		
4	3,128	0[7]	0	0.0	10	0	0	10	0	10	10	2,174	2,056		
5	246.6	44.1	36.4	0.2	2	0	0	0	0	2	2	1,675	1,665		
6	3,495.9	67.3	74.8	0.4	73	2	1	35	10	13	23				

Line Number	Pressure, Lb. per Sq. In.[e]: Initial	Pressure: Average at End of 1933	Pressure: Average at End of 1934	Character of Oil, Approx. Average during 1934: Gravity A.P.I. at 60° F.: Maximum	Gravity: Minimum	Gravity: Weighted Average	Sulfur, Per Cent	Base[f]	Character of Gas, Approx. Average during 1934: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934: Name	Depth of Hole in Feet
1	0	0	0	38	24	34	1.0–2.5	P			Rock Canyon Conglomerate	Tri	L	Por	2	T	69	Per Coconino-Supai	2,195
2	0	0	0	40	39	39	0.24	M			Goodridge	Pen	S	Por	6	S	116[3]	Pen. Hermosa	3,633
3	750	700	625						CO$_2$ gas	0	Moenkopi-Kaibab	Tri-Per	S	Por	21	AF	1	Per. Kaibab	3,235
4	750	325	325						1,080	0	Dakota-Morrison	Cre L	S	Por	*y*	D	3	Jur. Kayenta	3,045
5	580	320	270						980	0	Morrison	Cre L	S	Por	10	AF	3	Jur. Nugget	2,720
6	—	—	—	—	—	—	—	—											

[b] Footnotes to column headings and explanation of symbols are on page 249.

[1] 515 to 815 ft., depending on position of well on monoclinal structure.

[2] Abandoned.

[3] Includes assessment holes.

[4] Pumping with vacuum.

[5] Discovered 1923; began producing 1931.

[6] Discovered September, 1924; began producing February, 1927.

[7] Shut in since February, 1931.

[8] Discovered 1925; began producing 1929.

TABLE 2.—*Summary of Drilling Operations in Utah*
(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1935									Completed during 1934		Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes								Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes	Productive Wells (For Details, See Table 1)	Within Fields	Exploratory
	Total Depths, Ft.							Total		Total Depths, Ft.			
	0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000			1,000–2,000			
Box Elder	1	1	2	0	1	0	0	5	0	0	0	0	1[2]
Carbon	0	1	1	0	0	0	0	2	2	0	0	0	0
Daggett	0	0	0	0	1	1	0	2	0	0	0	0	1[1]
Davis	0	0	1	0	0	0	0	1	0	0	0	0	0
Duchesne	0	0	0	0	1	0	0	1	0	0	0	0	0
Emery	1	3	2	2	0	0	0	8	2[2]	0	0	0	0
Garfield	0	0	0	1	0	0	0	1	0	0	0	0	0
Grand	8	10	6	3	3	1	1	32	12[3]	0	0	0	0
Kane	0	0	0	0	1	0	0	1	0	0	0	0	0
Millard	0	1	0	1	0	0	0	2	0	0	0	0	0
Salt Lake	1	1	0	0	0	0	0	2	0	0	0	0	0
San Juan	119	2	2	2	3	3	0	131	9	0	1	0	0
Summit	0	0	0	2	0	0	0	2	0	0	0	0	1[2]
Uintah	1	4	4	0	0	0	0	9	2	1	0	0	0
Utah	1	1	1	0	0	0	0	3	0	0	0	0	1[2]
Washington	70	0	2	0	0	0	0	72	50	0	1	1	3[2]
Wayne	0	0	3	1	0	1	0	5	0	0	0	0	0
Totals	202	24	24	12	10	6	1	279	77	1	2	1	7

[1] Gas well, shut down for winter. To be deepened during 1935.
[2] For details see text.
[3] Cisco, 10 wells; Harley, 2 helium wells shut in by U.S. Government.

from 3120 to 3165 ft. The gas contains 1.31 per cent helium. The U.S. Government carefully plugged the well, withdrew the lands from public entry and established them as Helium Reserve No. 1, containing 12,600 acres.

Southwestern Utah

Washington County—Virgin Anticline.—Exploratory drilling on the various domes of this anticline, such as Bloomington, Harrisburg and Punchbowl, has been carried on for 15 years and is still active. No. 2 Escalante well of the Arrowhead Petroleum Co., the deepest well of this region, has now reached 4100 ft. and has encountered oil saturation at various horizons in the Pennsylvanian and lower series. The oil is of paraffin base and 36° Bé. gravity. The Virgin anticline is bounded along its flanks by major faults and commercial production from it is improbable. However, oil indications encountered are encouraging contemplated exploratory drilling on Circle Cliffs and other anticlines in South Central Utah.

Southeastern Utah

Grand and San Juan Counties.—No exploratory drilling was done in these counties during 1934. Frank Shafer No. 1 well, the discovery well on Cane Creek anticline in T.27S., R.21E., which blew itself in during December, 1925, registered rock pressures of 935 lb. for three years and produced sufficient oil for the drilling of another well, remains to be offset along the fracture zone from which it produced its oil in the Paradox formation. This well was cemented in 1928 after 4-in. and 6-in. casings had collapsed and production had been shut off by recrystallization of salt in the well and in the tubing. All deep wells drilled on the Salt Valley anticline in Grand County have indicated the presence of potassium salts in the Paradox formation of lower Pennsylvanian age. Potash well No. 24, drilled by the U.S. Geological Survey during 1931, was shut down at a depth of 1731 ft. on account of lack of appropriations for further work. It did not reach the lower potash zone encountered in King No. 1 well. Conclusive evidence as to presence or absence of potash minerals in quantity has not as yet been established. As the Paradox formation occupies a large part of southeastern Utah and southwestern Colorado, a more progressive exploration program, such as was carried on in Texas and New Mexico, seems warranted. The analyses of oils from the Balsley well on Salt Valley anticline and the Frank Shafer well on Cane Creek anticline are as follows:

Balsley Well, Salt Valley

Oil green, paraffin base, sp. gr. 36.8 Bé.

Gasoline	22.5
Ref. oil	6.0
Gas oil	7.0
Paraffin dist	58.5
Base and loss	6.0
	100

Frank Shafer Well, Cane Creek

Oil green, paraffin base, sp. gr. 38.6 Bé.

Gasoline	21.2
Kerosene	14.0
Gas oil	10.8
Paraffin wax	53.0
Coke	1.0
Sulfur	tr.
	100

Geophysical work was done during the year in the northern part of Grand County to the west and northwest of the Uncompaghre uplift in connection with the development of possible shore-line conditions in the Paradox formation.

During 1925 and 1926 two wells were drilled on the Harley dome in Grand County. This dome contains approximately 320 acres within a closure of 100 ft. The wells encountered helium-rich natural gas at 560 to 590 ft. in the McElmo formation of lower Cretaceous age and at 860 to 1148 ft. in the Entrada sandstone of Upper Jurassic age. The amount of gas is estimated at 5,000,000 cu. ft., R.P. 155 lb. The wells have been closed in and private operations have been indefinitely suspended by the

U.S. Government. In San Juan County gas high in nitrogen content was encountered at Boulder Knoll and carbon dioxide gas farther south on San Juan East anticline. These discoveries were made during 1928 but no development work has followed. Minor gas blow-outs were encountered in many test wells of this region.

Northeastern Utah

Daggett County—Clay Basin Anticline.—Murphy No. 2 well in sec. 21, T.3N., R.24E., was started by Mountain Fuel Supply Co. during August, 1934; it blew itself in Nov. 4, 1934 at a depth of 5654 ft. but was soon brought under control and drilled to 6030 ft. The well encountered 3,700,000 cu. ft. of gas, R.P. 2110 lb., from 5328 to 5344 ft. in the Frontier formation of Cretaceous age; 32,000,000 cu. ft. of gas, R.P. 2300 lb. (approx.) from 5627 to 5697 ft. (approx.) in the Dakota sandstone of Cretaceous age. Gas-saturated core 22 ft. long had been obtained from the Morrison formation of Jurassic age between 6008 and 6030 ft., when the well was shut down for the winter. The well will be deepened to 7000 ft. during 1935 to test lower sands. The well was drilled to increase gas reserves back of the Salt Lake City-Ogden natural gas system. A pipe line 23 miles long is required to connect with the main line. A second well probably will be drilled lower on structure before pipe line is built. There are 5700 acres within the 450-ft. dip closure; 2000 acres are now estimated as probably productive. This is the first well in the field to reach the Dakota sandstone, Producers & Refiners Corporation's No. 2 having been shut in in 1927 after encountering 3,276,000 cu. ft. of gas, R.P. 2110 lb. in the Frontier formation. Exploratory drilling on other anticlines in northeastern Utah is anticipated.

North Central Utah

Box Elder County.—The Leonora-Raddatz well on the shore of Great Salt Lake in sec. 14, T.9N., R.8W., had reached a depth of 2300 ft. in Pennsylvanian rocks in December.

Summit County.—The Longwall Petroleum Co. well on the Chalk Creek anticline in T.3N., R.5E., is drilling at 1000 ft. in Cretaceous rocks.

Utah County.—Diamond Oil Co. No. 4 well in sec. 16, T.8S., R.5E., is drilling in Cretaceous rocks at a depth of 3580 feet.

PRODUCING FIELDS

Virgin Field, Washington County.—This field, in T.41S., R.12W., on a structural terrace, has produced small amounts of oil since its discovery in 1907. Spasmodic drilling of shallow wells probably will continue in the future; no major discoveries of importance are anticipated.

San Juan Field, San Juan County.—This field, discovered in 1908, is producing small amounts of oil from shallow wells (200 ft.) in a syncline.

TABLE 3.—*Well Data, Utah*

Line No.	County	Area	Structure[1]	Operator	Location	Name of Well
1	Box Elder..	Penrose	*y*	Utah-Penn Oil Co.	NW.NW. 3-10N.- 4W.	*y*
2		Rozel	*y*	Lakeside Oil Co.	SW.SE.31- 9N.- 7W.	*y*
3		Rozel	*y*	Leonora Raddatz	C. 14- 9N.- 8W.	*y*
4		Utah Hot Springs	*y*	*y*	*y*	*y*
5		*y*	*y*	*y*	*y*	*y*
6		*y*	*y*	*y*	*y*	*y*
7	Carbon....	Farnham	*AF*	Utah Oil Refining Co.	NE.SW. 12-15S. -11E.	No. 1
8		Farnham	*AF*	Carbon Dioxide and Chemical Co.	SE.SW. 12-15S. -11E.	*y*
9		Price	*y*	Price Petroleum Co.	SW.NE. 16-14S. -10E.	*y*
10		South Wellington	*y*	Holmes-McGee	NW.NE. 14-15S. -10E.	No. 1
11	Daggett...	Clay Basin	*AF*	Producers and Refiners Corp.	NW.SW. 22- 3N.-24E.	No. 1
12		Clay Basin	*AF*	Producers and Refiners Corp.	SW.NW. 22- 3N.-24E.	Murphy No. 1
13		Clay Basin	*AF*	Mountain Fuel Supply Co.	NE.NE. 21- 3N.-24E.	Murphy No. 2
14	Davis.....	Farmington	*y*	*y*	*y*	*y*
15	Duchesne..	Duchesne	*Ay*	Midwest Ref. Co.-Utah Southern	SE.SW. 13- 4S. - 6W.	No. 1
16	Emery.....	San Rafael swell	*Af*	Leonard Petroleum Co. *Ai*	SE.NW. 8-21S. - 9E.	*y*
17		San Rafael swell	*Af*	Leonard Petroleum Co. *Ai*	NW. 5-21S. - 9E.	*y*
18		San Rafael swell	*Af*	Carter Oil Co. *A*	SE.NE. 34-23S. -11E.	San Rafael No. 1
19		Woodside	*A*	Utah Oil Refining Co.	SW.SE. 12-19S. -13E.	Fitzhugh No. 1
20		Huntington	*Ay*	Ohio Oil Co.	2-17S. - 8E.	No. 1
21		Flattops	*Af*	Des Moines Oil Co. *Ai*	SW. 19-26S. -13E.	Des Moines
22		Last Chance	*A*	Ramsey Petroleum Corp.	SW.NE.SW. 18-26S. - 7E.	Senior No. 1
23		Greenriver	*y*	*y*	1-21S. -15E.	*y*
24		Greenriver	*y*	*y*	18 mi. W. of Green River	*y*
25		Greenriver	*y*	*y*	17 mi. NW. of Green River	*y*
26	Garfield....	Circle Cliffs	*Af*	Ohio Oil Co.	SE.SW. 24-34S. - 7E.	No. 1
27	Grand.....	Thompson	*i*	Hope Syndicate	NW.NE. 21-22S. -20E.	No. 1
28		Thompson	*i*	Raddatz, Vogel & Travis	SE.SE. 9-22S. -20E.	No. 1
29		Crescent	*AsF*	W. M. Armstrong	SE.SE. 9-22S. -19E.	Armstrong No. 1
30		Crescent	*AsF*	Big Six Oil Co.—Utah Oil Ref. Co.	NE.SE. 10-22S. -19E.	Randall No. 1
31		Crescent	*AsF*	Brendel Oil & Gas. Co.	NW.NE 9-22S. -19E.	Brendel No. 1
32		Crescent	*AsF*	Crescent Eagle Oil Co.	SW.SE. 4-22S. -19E.	No. 1
33		Crescent	*AsF*	Sandburg Petroleum Co.	NE.SW. 7-21S. -19E.	No. 1
34		Crescent	*AsF*	Western States Development Co.	SW.SW. 27-21S. -19E.	No. 1
35		Salt Valley	*AsF*	Utah Southern Oil Co.	NE.SE. 13-23S. -20E.	King No. 1
36		Salt Valley	*AsF*	Utah Southern Oil Co.	NW.NE. 31-23S. -21E.	Balsley No. 1
37		Salt Valley	*AsF*	Wyoming Cons. Oil Co. West. Allies	SE. 5-23S. -20E.	K. Levi well
38		Salt Valley	*AsF*	U.S. Geological Survey	SE. cor 13-23S. -20E.	Potash test No. 24
39		Salt Valley	*AsF*	Raddatz et al.	4-23S. -20E.	*y*
40	Grand.....	Cisco	*Af*	Cart-Barnes	NE.SW. 14-20S. -21E.	No. 1
41		Cisco	*Af*	Midwest Refining Co.	SE.NE. 25-20S. -21E.	Jenkinson No. 1
42		Cisco	*Af*	Crystal Carbon Co.	SE.SE. 24-20S. -21E.	No. 2
43		Cisco	*Af*	Crystal Carbon Co.	SW.NW. 25-20S. -21E.	No. 3
44		Cisco	*Af*	Crystal Carbon Co.	NE.SE. 23-20S. -21E.	No. 4
45		Cisco	*Af*	Crystal Carbon Co.	NW.NE. 26-20S. -21E.	No. 5
46		Cisco	*Af*	Engstrom-Wegeman	NE.SW. 13-20S. -21E.	No. 1
47		Cisco	*Af*	Navajo Petroleum Corp.	SW.SE. 2-20S. -21E.	No. 1
48		Cisco	*Af*	Perfection Oil and Gas Co.	NW.SW. 30-20S. -22E.	No. 1
49		Cisco	*Af*	Perfection Oil and Gas Co.	SE.NE. 31-20S. -22E.	No. 2
50		Cisco	*Af*	Perfection Oil and Gas Co.	NE.SE. 30-20S. -22E.	No. 3
51		Cisco	*Af*	Urban-Terril	NE.NW. 32-20S. -22E.	No. 1
52		Cisco	*Af*	Midwest-Utah Oil Refining Co.	NW.SW. 30-20S. -22E.	C.M. Rath No 1
53		Cisco	*N*	*y*	6-21S. -24E.	*y*
54		Cisco	*N*	*y*	6-21S. -24E.	*y*
55		Cisco	*i*	Utah Southern Oil Co.	SE. 26-21S. -23E.	No. 1 State
56		Harley	*A*	Home Oil Co.	NE.NE. 4-19S. -25E.	No. 1
57		Harley	*A*	Home Oil Co.	SE.NE. 4-19S. -25E.	No. 2
58		Green River	*AF*	Marland Oil Co.	NW.SE. 35-21S. -16E.	Culbertson No. 1
59		Green River	*i*	Western Allies-Levi	SW.SW. 15-21S. -16E.	Elgin well
60		Green River	*i*	Western Allies-Levi	NW.NE. 25-23S. -18E.	Levi No. 1
61		Green River	*i*	Western Allies-Levi	SW.NE. 35-22S. -17E.	Levi No. 2
62		Green River	*i*	Western Allies-Levi	NW.NW. 26-22S. -17E.	Levi-Keystone
63		Green River	*S*	Western Allies-Levi	NW.SW. 26-23S. -19E.	Klondike well
64		Green River	*S*	Western Allies-Levi	SW.SE. 18-23S. -19E.	Queen well
65		Green River	*i*	Western Allies-Levi	NE.NE. 20-21S. -17E.	Collins well

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[1] *y* Information not determinable from data available to the author.

A, anticline; *As*, salt anticline; *AF*, anticline with faulting as major feature; *Af*, anticline, faulting minor feature; *Ay*, anticline, importance of faulting not known to author; *N*, nose; *i*, inclined strata or outside closing contour lines of anticline; *S*, syncline; *D*, dome; *T*, terrace; *M*, monocline.

TABLE 3.—(*Continued*)

Line No.	Depth, Ft.	Date Completed	Kind of Well[2]	Status of Well Dec. 31, 1934	Remarks
1	4100	7/24/31	Dry	Abandoned	
2	2710	4/20/29	*y*	*y*	
3	2300		*y*	Shut down for winter	
4	600	Prior/05	*y*	Abandoned	Oil test; see U.S.G.S. *Water Supply Paper* 149.
5	2755	*y*	*y*	Abandoned	
6	1350	*y*	*y*	Abandoned	
7	3235	1/ 8/24	CO_2 gas	Producing	Gas used for manufacture of dry ice.
8	3114	6/15/30	CO_2 gas	Producing	Gas used for manufacture of dry ice.
9	3335	9/ 1/30	*y*	Abandoned	
10	2462	9/10/27	*os*	Abandoned	
11	4000	10/ 1/25	Dry	Abandoned	Lost hole.
12	5445	4/ 6/27	Gas	Shut in	3,276,000 cu. cu. ft. R.P. 2140 lb. Frontier formation. Cret.
13	6030		Gas	Shut in; to be deepened to 7000 ft. 32 mil. plus cu. ft.	R.P. 2300 lb. See text.
14	2000	Prior/05	*y*	Abandoned	Oil test; see U.S.G.S. *Water Supply Paper* 149.
15	4760	6/19/28	*ogs*	Abandoned	
16	2660	5/ *y*/22	Dry	Abandoned	Sulfur water.
17	460	*y*/ *y*/22	Dry	Abandoned	
18	3035	2/ 1/22	Water	Abandoned	
19	3375	2/ 7/24	He gas	Plugged by U.S. Govnmt.	Est. 21 mil. cu. ft. R.P. 900 lb. Permian. See text.
20	3100	11/ 4/21	Dry	Abandoned	
21	2910	*y*/ *y*/14	*ogs*	Abandoned	Several oil sands. Could not shut off water. Trias.-Perm.
22	3168		Gas	Plugging back to gas sand	21 mill. plus cu. ft. R.P. 410 lb. Trias.-Perm. See text.
23	1400	Prior/05	*y*	Abandoned	See U.S.G.S. *Water Supply Paper* 149.
24	1335	Prior/05	*y*	Abandoned	See U.S.G.S. *Water Supply Paper* 149.
25	1325	Prior/05	*y*	Abandoned	See U.S.G.S. *Water Supply Paper* 149.
26	3212	11/17/21	Water	Abandoned	Did not reach lower Pennsylvanian.
27	1400	10/22/25	Dry	Abandoned	
28	1417	10/ 3/25	Dry	Abandoned	
29	1223	2/27/27	*os*	Abandoned	Did not reach all prospective horizons.
30	1710	10/15/28	*os*	Abandoned	Lost hole.
31	4125	10/13/32	*gs*	Shut down	Potash showing 3462–3479 Paradox formation. Lower Pen.
32	4000	*y*/ *y*/26	*ogs*	Abandoned	Potash showing carnallite crystals on bailer. Paradox Form.
33	2470	10/ *y*/26	*y*	Abandoned	*y*
34	2171	11/26/30	*y*	Abandoned	*y*
35	3830	*y*/ *y*/30	*y*	Abandoned	Potash showing, two horizons, Paradox form. Lower Pen.
36	6120	*y*/ *y*/32	Oil	Standing. Drilled to 5367 during 1932.	Small well. See text for analysis of oil.
37	825	4/10/19	*os*	Abandoned	First well to encounter salt of Paradox form.
38	1731	*y*/ *y*/31	*y*	Abandoned	Did not reach lower Potash zone of King No. 1 well.
39	1388	*y*/ *y*/25	*y*	Abandoned	Location of this well doubtful.
40	501	4/ 3/28	Dry	Abandoned	Assessment hole, oil and gas permit.
41	1960	10/11/24	Gas	Shut in	
42	2423	11/14/26	Gas	Shut in	
43	2057	5/ 4/27	Gas	Shut in	
44	2032	8/21/27	Gas	Shut in	
45	2271	6/11/28	Gas	Shut in	
46	500	8/12/28	Dry	Abandoned	Assessment hole, oil and gas permit.
47	2965	6/ 1/29	Dry	Abandoned	
48	1992	8/25/26	Gas	Shut in	
49	2207	10/26/27	Gas	Shut in	
50	2200	9/22/28	Gas	Shut in	
51	1960	8/ 9/28	Gas	Shut in	
52	3045	4/13/25	Gas	Shut in	Deep test well in Cisco field.
53	1000–	Prior/24	Oil	Abandoned	Small oil well near Cisco town.
54	1300	Prior/24	Oil	Abandoned	Small oil well near Cisco town.
55	2431	*y*/ *y*/30	Dry	Abandoned	Paradox formation shore-line test; struck granite.
56	801	8/18/24	He gas	Shut in	Operations suspended by U.S. Government.
57	1675	7/ *y*/25	He gas	Shut in	Est. 5 mil. cu. ft. R.P. 155 lb. U.S. Government suspended operations.
58	3824	10/ 2/26	*ogs*	Abandoned	Oil and gas shows from 1525 ft. to 3170 ft.
59	1000	Prior/12	*os*	Abandoned	
60	530	Prior/12	*y*	Abandoned	
61	1500	Prior/12	*os*	Abandoned	
62	425	Prior/12	*y*	Abandoned	
63	700	Prior/12	*os*	Abandoned	
64	920	Prior/12	*y*	Abandoned	
65	2100	Prior/12	*os*	Abandoned	

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[2] *os*, oil showing; *ogs*, oil and gas showing; *gs*, gas showing; He gas, helium-rich natural gas; CO_2 gas, carbon dioxide main constituent of gas.

TABLE 3.—(*Continued*)

Line No.	County	Area	Structure[1]	Operator	Location	Name of Well
66		Moab	*AsF*	Embar Oil Co. (Big. Six-West. Allies)	NW.NW. 34-25S. -21E.	Big. Six No. 2
67		Moab	*AsF*	Utah Oil Development Co.	NW.NW. 8-26S. -22E.	Elec. Light Plant No. 1
68		Moab	*AsF*	Western Allies-Big Six Oil Co.	NW.NE. 12-26S. -21E.	Big. Six No. 1
69		Cane Creek	*Asf*	Midwest-Utah Southern Oil Co.	SE.NW.SE. 25-26S. -20E.	J. L. Shafer No. 1-A
70	Kane......	Paria	*Af*	Midwest Exploration Co.	SW.SE. 14-39S. - 1W.	No. 31 C. G. Parry
71	Millard....	Black Rock	*A*	Beaver Valley Oil Co.	NW.NE. 20-25S. - 9W.	No. 1
72		Black Rock	*A*	Beaver Valley Oil Co.	SW.SE. 19-25S. - 9W.	No. 2
73	Salt Lake..	*y*	*y*	Tower Petroleum Co.	Salt Lake City	*y*
74	Salt Lake..	*y*	*y*	Western Petroleum Drilling Co.	NE.SE. 21- 1N.- 1W.	*y*
75	San Juan..	Cane Creek	*AsF*	Midwest-Utah Southern Oil Co.	NW.NE. 6-27S. -21E.	F. Shafer No. 1 Discovery
76		Cane Creek	*Asf*	Snowden McSweeney	SW.NE. 5-27S. -21E.	Prommel No. 1
77		Shafer	*Asf*	Midwest-Utah Southern Oil Co.	SE.SE. 16-27S. -20E.	J. H. Shafer No. 1
78		Lockhart	*As*	Equity Oil Co.	SW.SW. 16-28S. -20E.	Hazlewood No. 1
79		Gibson	*Asf*	Empire Gas & Fuel Co.	NW.NW 6-30S. -21E.	Kimball No. 1
80		Gibson	*Asf*	Utah Petroleum Corp.	NW.NE. 1-30S. -20E.	Geoghan No. 1
81		Gibson	*Asf*	Deseret Petroleum Co.	NE. 3-30S. -20E.	Rose No. 1
82		Gibson	*Asf*	Western States Development Co.	SW. 34-29S. -20E.	*y*
83		Elk Ridge	*Af*	Midwest Refining Co.	NW.SW. 30-34S. 19E.	Hughes No. 1
84	Jan Juan...	Boulder Knoll	*A*	Boulder Knoll Oil & Gas Co.	NW.NW. 17-34S. -25E.	Endter No. 1
85		Lisbon	*AsF*	Union Oil Co. of California	NE.NW. 16-30S. -25E.	*y*
86		Boundary Butte	*Af*	Midwest Ref.-Continental Oil Co.	C.NE. 27-43S. -27E.	*y*
87		Organ Rock	*Af*	Wilson Cranmer	35-42S. -14E.	*y*
88		Cedar Mesa	*Af*	Utah Southern Oil Co.	NE. 28-40S. -18E.	Noble No. 1
89		San Juan East anticline	*Af*	Utah Southern Oil Co.	27-41S. -19E.	Canyon No. 1
90		San Juan	*S*	Various companies	40-41S. 18-19E.	125 shallow wells.
91	Summit....	Chalk Creek, Coalville	*A*	Ohio Oil Co.	NW.SE. 6- 2N.- 6E.	*y*
92		Chalk Creek, Coalville	*A*	Western Empire Petroleum Co.	16- 2N.- 5E.	*y*
93		Chalk Creek, Coalville	*A*	Longwall Petroleum Co.	SE.SW.SE. 35- 3N.- 6E.	*y*
94	Uintah....	Ashley Valley	*AF*	Utah Oil Refining Co.	SW.NW. 23- 5S. -22E.	No. 1
95		Ashley Valley	*AF*	Utah Oil Refining Co.	NE.SW. 23- 5S. -22E.	No. 2
96		Ashley Valley	*AF*	Utah Oil Refining Co.	SW.NW. 23- 5S. -22E.	No. 3
97		Ashley Valley	*AF*	Utah Oil Refining Co.	SE.NW. 22- 5S. -22E.	No. 4
98		Ashley Valley	*AF*	Uintah Gas Co.	NW.NW.SW. 23- 5S. -22E.	No. 5
99		Dog Valley	*y*	Western Venture Corp.	NE.SW. 8- 5S. -21E.	No. 1 Spohr
100		Dog Valley	*y*	Home Oil Co.	SE.NW.SE. 6- 5S. -21E.	No. 1 Krumvieda
101		Hill Creek	*A*	Utah Oil Refining Co.	NW. 32-14S. -20E.	*y*
102		Myton	*y*	Utah Southern Oil Co.	SE.SE. 29- 4S. - 1E.	*y*
103		Myton	*y*	Uintah Oil & Exploration Co.	SW.NE. 26- 6S. -19E.	*y*
104		Neal Dome	*A*	Maude Ellen Oil Co.	NE.NW.SE. 28- 6S. -21E.	*y*
105	Utah......	Diamond Fork	*y*	Diamond Oil Co.	SW.NE. 10- 9S. - 4E.	No. 1
106		Diamond Fork	*y*	Diamond Oil Co.	NW.SW. 3- 9S. - 4E.	No. 2
107		Diamond Fork	*y*	Diamond Oil Co.	NE.NE. 29- 8S. - 5E.	No. 3
108		Diamond Fork	*y*	Diamond Oil Co.	SE.NW. 16- 8S. - 5E.	No. 4
109	Washington	Beehive	*D*	St. George Oil Co.	NE.NW. 30-43S. -14W.	*y*
110		Bloomington	*A*	Mid American Oil Co.	SE.NW. 17-43S. -15W.	*y*
111		Bloomington	*A*	Arrowhead Petroleum Corp.	NW.NE. 19-43S. -15W.	No. 2 Escalante
112		Harrisburg	*A*	Virgin Dome Oil Co.	NW.NW. 16-42S. -14W.	No. 1
113		Punchbowl	*D*	Arrowhead Petroleum Corp.	SE.SW.NE. 1-43S. -15W.	No. 1A
114		Virgin	*T*	Virgin Petroleum Co.	NW.NE. 23-41S. -12W.	No. 2
115		Virgin	*T*	Jerome L. Anders	SE.NW. 6-41S. -11W.	*y*
116		Virgin	*T*	Various operators	41S. -12W.	119 shallow wells
117	Wayne....	Barrier Creek	*A*	Phillipps Petroleum Co.	NE. 16-27S. -16E.	Schick No. 1
118		Cainville	*A*	Ohio Oil Co.	29-28S. - 8E.	No. 1
119		Nequoia Arch	*M*	Texas Production Co.	NW.SE. 34-29S. -16E.	Conley well
120		Nequoia Arch	*M*	Mount Vernon Oil Co.	4-27S. -12E.	Mt. Vernon well
121		Sweetwater	*Af*	Texas Production Co.	C.NW. 5-27S. -14E.	Shipley No. 1

TABLE 3.—(*Continued*)

Line No.	Depth, Ft.	Date Completed	Kind of Well[2]	Status of Well Dec. 31, 1934	Remarks
66	5345	4/18/28	*os*	Abandoned	Numerous shows of light oil from Paradox formation; PenL.
67	1550	11/ *y*/26	*os*	Abandoned	Stopped in Paradox formation.
68	2450	4/ *y*/19	*os*	Abandoned	First well to find oil in Paradox formation.
69	4107	*y*/ *y*/29	*ogs*	Abandoned	Stopped in Paradox formation.
70	4436	8/18/30	*y*	Abandoned	
71	3500	3/ 1/30	*y*	Abandoned	Lost hole.
72	1545		*y*	Inactive since Jan. 3, 1931	
73	930	8/ *y*/27	*y*	Abandoned	
74	1985	12/ *y*/31	*y*	Shut down indefinitely	
75	5000	3/11/27	Oil, gas	Plugged; collapsed casing; cem.	Discovery well; oil and gas from three horizons. See text.
76	3520	6/27/27	*y*	Abandoned	
77	5863	11/ 5/27	*ogs*	Abandoned	
78	527	12/20/26	Dry	Abandoned	Oil and gas permit assessment hole.
79	4136	7/ 9/27	*ogs*	Abandoned	Several oil and gas showings in Paradox form. PenL.
80	1643	5/ *y*/27	*y*	Abandoned	
81	517	2/ *y*/27	Dry	Abandoned	Oil and gas permit assessment hole.
82	500	*y*/ *y*/27	Dry	Abandoned	Oil and gas permit assessment hole. May be location only.
83	4422	11/ 5/27	Dry	Abandoned	Stopped in hard schist basement rocks.
84	2640	*y*/ *y*/28	Gas	Shut down indefinitely	See table of gas analyses.
85	5010	10/15/27	*ogs*	Abandoned	Paradox form. 1420–5010; several oil and gas showings.
86	5612	*y*/ *y*/29	Gas	Abandoned	Open flow ¾ mil. at 4525 ft. R.P. 1000 lb.
87	2253	*y*/ *y*/23	*ogs*	Abandoned	Diamond-drill hole.
88	3640	2/24/28	*gs*	Abandoned	Well bottomed in mica schist.
89	1870	*y*/ *y*/28	CO_2 gas	Abandoned	Well bottomed in mica schist gas 673–971. See table gas analyses.
90	250		Oil and dry	See Table 1	Includes assessment holes.
91	3201	11/ 6/24	*y*	Abandoned	
92	3870	*y*/ *y*/27	*y*	Abandoned	
93	1000		*y*	Drilling	No detailed data available.
94	1685	4/13/25	Gas	Producing	See Table 1 for details.
95	709	10/ *y*/27	Dry	Abandoned	
96	2720	3/23/28	Gas	Producing	See Table 1 for details. Plugged back to 1683 ft.
97	2165	12/20/28	*y*	Abandoned	
98	1730	12/ 4/34	*y*	Abandoned	
99	1165	12/29/34	*y*	Abandoned	
100	1692	1/15/35	*y*	Abandoned	
101	2150	6/25/22	*y*	Abandoned	
102	3000	10/ 2/29	*y*	Abandoned	
103	1500	*y*/ *y*/22	*y*	Abandoned	
104	2552	11/ *y*/32	*y*	Shut down indefinitely	
105	941	*y*/ *y*/21	*y*	Abandoned	
106	2151	*y*/ *y*/26	*y*	Abandoned	
107	1691	6/ 1/29	*y*	Abandoned	
108	3585		*y*	Drilling	Drilled 43 ft. during 1934.
109	970	10/ *y*/29	*y*	Shut down indefinitely	
110	2532	5/16/31	*y*	Abandoned	
111	4231		*os*	Drilling	Eight oil showings in PenL. Paraffin base, 36 Bé.
112	3400		*y*	Plugging off bottom water	Also reported as drilling.
113	850		*y*	Drilling	
114	2195	5/ 1/29	*y*	Shut down indefinitely	
115	899		*y*	Drilling	
116			Oil and dry		Wells 400 to 800 ft. deep. For details see Table 1.
117	5191	8/ *y*/29	Dry	Abandoned	Water in lower part of well.
118	3650	8/15/22	Dry	Abandoned	Water in lower part of well.
119	2250	4/ 4/24	Dry	Abandoned	
120	2200	*y*/ *y*/14	Oil	Abandoned	Small oil well; could not control water.
121	2875	8/ 9/28	Dry	Abandoned	Abandoned as crooked hole.

No major discoveries are anticipated although occasional drilling of shallow wells may take place in the future.

Farnham Field, Carbon County.—This field is producing carbon dioxide gas from one well for the manufacture of dry ice and allied products by the Carbon Dioxide & Chemical Co.

Cisco Field, Grand County.—No gas has been produced from this field since February, 1931. The Crystal Carbon Co. of Charleston, West Va., maintains a carbon-black plant in this field, which has a capacity of about 400 bags, or 5000 lb., of carbon black in 24 hr. The gas flow furnishes heat, light and motive power for the plant.

Ashley Valley Field, Uintah County.—The gas from this field is used in Vernal, Utah, for fuel. A well drilled by the Uintah Gas Co. during 1934 was abandoned during December at a depth of 1730 feet.

TABLE 4.—*Analyses of Gas from Fields in Utah*

Field, *County*	Percentage of Gas										Sample Taken or Analysis Contributed by (For Details See) (Acknowledgements)
	Carbon Dioxide	Oxygen	Methane	Nitrogen	Helium	Hydrogen Sulfide Gas	Ethane	Illuminants	Loss	Total	
Farnham, *Carbon*	91.20	1.47		6.51		0.20		0.62		100	Early sample by R. W. Calvert.
Farnham	98.30	0.00	0.30	1.14	0.03	0.23				100	Later sample by E. S. Shaw.
Clay Basin, *Daggett*	0.18		90.45	1.82		0.00	7.55			100	W. T. Nightingale.*
Woodside, *Emery*	31.70	0.27	0.00	62.30	1.31		5.70			101.28	U.S. Bureau of Mines, F. W. Wright.
Last Chance	5.00		74.00	16.00			3.00		2.00	100	
Cisco, *Grand*	2.3	0.00	93.70	0.20	0.00		3.8			100	E. S. Shaw.
Cisco	1.36	1.15	47.77	12.46			37.05			99.79	D. E. Winchester.
Harley	1.10	0.00	5.10	84.40	7.16		2.30			100.06	Helium Corp. of America.†
Harley	0.00		22.83	48.49	2.16		25.81			99.29	Helium Corp. of America.†
Boundary Butte, *San Juan*	0.26		48.05	22.78	0.76		28.15			100	Helium Corp. of America.
San Juan East Anticline	97.30			2.70	0.07					100.07	G. T Hansen.
Boulder Knoll	0.18		26.40	30.50	0.38		42.55			100.01	Helium Corp. of America.
Ashley Valley, *Uintah*	0.20	0.13	99.42	0.24	0.01					100	E. S. Shaw.

* From Frontier Horizon only; observed gravity, 0.618; gross B.t.u. 1078.
† These samples may have come from different horizons; see text.

ANALYSES

During the past 30 years about 100 exploratory wells have been drilled in Utah (Tables 2 and 3), many of them by crews unfamiliar with the easy drilling, but highly cross-bedded, massive sandstones encountered. A number of crooked holes have resulted which had to be abandoned before all prospective horizons were reached. A number of the exploratory wells were drilled prior to the present mechanical perfection of drilling equipment at times when 4000-ft. wells were considered extraordinary. Since 1926 extensive geological and paleontological studies have been carried on in the state and stratigraphic relations hitherto unknown have been revealed. These, coupled with a better drilling technique, may lead eventually to the discovery of additional oil and gas fields in the known petroliferous provinces of Utah.

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Oil and Gas Development in West Virginia during 1934

By David B. Reger,* Member A.I.M.E.

(New York Meeting, February, 1935)

Oil and gas and their derivatives continue to be stable products in West Virginia. In the midst of the cataclysmic happenings of 1930 to 1934, which have swept away banks and practically destroyed many other enterprises of presumably nonspeculative character, the possession of a royalty or working interest in a few old oil or gas wells has prevented disaster in literally thousands of homes. These old wells yield their daily quotas of basic commodities, which the public must have.

Fortunately, the facilities of disposal in the Appalachian Province are so ample and well managed that the owner of such equities may be reasonably certain that his proportionate share of existing markets will be afforded him without much effort on his part. In most cases these investments are free from encumbrance or hypothecation, therefore the main uncertainty is the date of ultimate exhaustion at the source. Generally, this is known to be fairly remote. The net result has been that individual owners part with such investments only as a last resort.

In sharp contrast to the action of the small owner of wells or royalties who has prudently refrained from jeopardizing his rather certain income by drilling new wells that may be failures, or of which the product may not be needed for the moment, has been the plight of various promotional enterprises in natural gas. Many of these ventures have been operated by amateurish remote control and practically all have been overloaded from the start with bonds and debentures, which could only be satisfied in a rising and expanding market; and with operating costs that have been exceedingly high because of widely scattered producing units and large overheads. Many of these promotions are now in receivership or bankruptcy and in various instances the original units have been recaptured by former owners and have again become profitable by reason of personal operation and elimination of all forms of overhead expense.

New Development

In 1934, the State issued 524 permits for drilling. According to the trade journals, 553 wells were completed, with 184 oil wells, 274 gas wells and 95 dry holes (Table 3).

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New Producing Areas

Ritchie County has surpassed all others in new drilling, with 154 completions as compared to 68 in Calhoun, which stands second. In Ritchie the Pike pool of Clay and Grant districts, discovered by the redrilling of formerly discredited territory, has furnished 23 new oil wells in the Big Injun sand, with capacities of 5 to 650 bbl., but with production mainly confined to 200 acres in or near the village. There have been eight dry holes, and two wells are now drilling.

In Ritchie County, also, drilling has continued with more or less profitable results in the Lost Run pool near Ellenboro, Grant and Clay districts. A barren zone apparently separates Lost Run from Pike, which is only 2 miles distant.

In Ritchie, also, a Big Injun sand gas well of 600,000 cu. ft. capacity at 600 ft. depth, has recently (January, 1935) been completed on the Burning Springs anticline at Petroleum, Grant district, indicating a possible revival of deeper drilling on this old structure, where earlier production is mostly in still shallower sands.

In Wetzel County several new gas wells have been drilled in Proctor district, one of which is near the village of Maud and represents a new discovery on a pronounced subsurface anticlinal nose.

In Union district, Wood County, a Maxton-sand gas well of 500,000 cu. ft. or more capacity at depth of 1600 ft. near Doyle, completed in January, 1935, is regarded by local operators as a significant find.

In Center district, Gilmer County, eight redrilled or new wells have found oil in a broken sandy zone of the Upper Devonian about 125 ft. below the Berea sand, possibly representing the Fifty-foot sand of the north. The largest well, completed in May, 1934, produced 1060 bbl., but has declined to 10 bbl. Generally the wells have averaged 25 to 30 barrels.

In Meade district, Upshur County, several additional Benson sand (Dev U) gas wells have been completed in the Frenchton area, where the value of this deep sand is now well established.

In Elk district, Kanawha County, north of Big Chimney, an oil well of about 150 bbl. capacity in the Oriskany sand (Dev L), at depth of 4759 ft., was completed in the late autumn of 1934. At present the well flows 25 bbl. Three previous completions in the same sand and locality are small gas producers. Five additional wells are drilling and two further locations have been made.

At Redhouse, Union district, Putnam County, a gas well of about 450,000 cu. ft. capacity in the Middle Devonian shale at depth of 2584 ft., or about 400 ft. below the Berea sand, and closely adjacent to a similar well by other parties, was completed in November by the West Virginia Rural Rehabilitation Corporation, which is building a subsistence homestead at the locality. The same organization has now filed an application for another well. Considerable interest has been aroused by the use of public funds for this purpose.

At Huntington, Cabell County, where an active development in the Genesee shale (Childres sand—Mid. Dev.) was in progress a year ago, operations are practically at a standstill, with only one completion in the last eight or nine months.

On Guyandot River immediately south of Saltrock, McComas district, Cabell County, 15 to 19 new gas wells in the Big Injun sand, varying in capacity from 500,000 to 1,500,000 cu. ft., have been drilled.

In Slab Fork district, Raleigh County, three or four gas wells have been drilled near Slab Fork village and two others are in progress. This locality is 25 miles southeast of the main oil and gas fields but is only 5 or 6 miles east of the Princeton-sand development of McGraw, Wyoming County.

In Browns Creek district, McDowell County, active drilling is in progress within the city limits of Welch, where gas wells of small capacity and only nominal rock pressure are being found in the outcropping or thinly buried sands of the Pottsville series (Pen.). Details of this discovery are not complete but 20 wells or more have been drilled. The known presence of a vast amount of gas, which is being released daily by coal mining in this region, indicates a possibility that the gas found at Welch may be percolating through broken strata toward the outcrop.

In Big Creek district, McDowell County, a well completed in September, 1933, had 213,000 cu. ft. of gas in the Berea sand at 3954 ft. but was drilled to the top of the Oriskany sand at 6639 ft., where the tools stuck and could not be recovered.

OPERATING TECHNOLOGY

Unit Operation

In the Sistersville area of Tyler County and the adjacent portion of Monroe County, Ohio, a pool of Keener and Big Injun Sand operators has been formed to repressure the sands and recover additional oil. As a preliminary step, a deep core-drill hole has been completed on the West Virginia side of the Ohio River at Sistersville. In this area many of the wells produce oil, gas and salt water, which are separated by gravity at the well mouth. The proposed unit embraces several thousand acres.

Acid Treatment

The use of hydrochloric acid for treating limestone wells is rapidly gaining favor among operators of central and southern West Virginia, where production is often found in the Big Lime (Greenbrier, Mis.). In some instances the open flow of an old gas well has been increased nearly 10 times. In others a lime well that made only a showing of oil has become a commercial producer. Owing to the low cost of treatment —$300 to $400 per well—it would appear that extensive use of this process may follow.

Deep Sand Exploration

For many years the Bayard sand (Catskill, Up. Dev.) was regarded by operators of northern West Virginia as the lowest formation in which production might be anticipated. In southern West Virginia, where the Catskill is absent, the Berea sand (Pocono, Mis.) was considered the last hope for oil and gas. Drilling was carried to deeper levels in some cases but usually was barren of good result.

As early as 1897, however, a well was drilled through the Oriskany sand (L. Dev.) at Central City, near Huntington, Cabell County, by Judge T. H. Harvey. For many years geologists who studied the record failed to recognize this formation.

Within comparatively recent years deeper drilling has proved the extensive presence of gas in the Upper and Middle Devonian. In northern West Virginia gas in the Elizabeth, Speechley, Riley and Benson sands of the Chemung series is now regarded as commonplace; and in the southwestern part of the state an even more extensive gas saturation of the Genesee (Childres sand) and other shales of the Middle Devonian has been abundantly proved.

The rock column beneath these shales is still a region of doubt. To date 45 wells have been drilled through the limestone, or limestones, of basal Middle Devonian age, overlying the Oriskany sand and commonly termed the Corniferous. In the writer's opinion this limestone may be the true Corniferous in some cases and in others it may be the Lower Selinsgrove resting upon the Oriskany by reason of unconformity. In any case no production has been found in it.

To the Oriskany sand the same number of tests (45) have been made with slightly more encouraging results, although in several cases no sand has been found. To date there have been five gas wells, one oil well, and one combination oil and gas well. A fact of much significance is the known presence of gas and oil in large quantities on the Cambridge anticline in Guernsey County, Ohio, about 50 miles from the West Virginia line. Contrary to the general rule, the Oriskany has shown very little salt water in West Virginia.

The Newburg sand, which is a widely persistent lentil in the Niagara lime (Sil.), has been tested 11 times, with four rather good gas wells and seven dry holes, some of the latter having made creditable shows. In view of these results, and of the prolific production that has been found in northeastern Ohio, near Cleveland and Akron, the possibilities of the Newburg appear rather good in West Virginia.

The so-called "Clinton" sand of Ohio, which in reality is the White Medina (Sil.) of New York state, has been tested seven times with barren results, except that a show of oil was recorded in Mason County.

The Trenton lime (Ord.), which probably is 400 to 700 ft. thick in the West Virginia oil and gas fields, has been tested to a depth of 65 ft. in Roane County, without production.

The summarized result of these deep tests is indicated in Table 4.

PROBABLE LINES OF NEW DEVELOPMENT

In addition to routine drilling in old areas where new pools of considerable value, like Lost Run, Pike and Saltrock, remain to be discovered, there will be a constant effort to find new production by deeper drilling in old and new territory; and perhaps an equally persistent effort to extend the productive belt southeastward toward the Allegheny Mountain region. The use of acid, also, will no doubt revive production in declining lime wells and may bring into commercial production various marginal areas where shows of oil and gas have been found.

STATISTICS

In Table 1 are the production statistics of West Virginia as far as the writer regards it prudent to carry these details. In a former volume, Smith[1] has made a serious effort toward the classification of the state by pools, of which he lists 154. In a previous publication Arnold and Kemnitzer[2] list 270 pools as of 1929, the writer being partly responsible for the data.

Many of these localities, which may have appropriately been termed pools in the years of their respective discoveries, have entirely lost significance at the present time by reason of further drilling which has merged them into larger units. The boundaries of production in any given locality of the state, in fact, are seldom set by any definite alignment of dry holes with regard to structure. A more vital governing factor is the lithology of the sands, which often prevents accumulation of oil or gas in structures where otherwise it might be found, or which, conversely, causes accumulation in synclines or on smooth monoclinal slopes.

In the present paper the production of the state has been divided into 50 "producing areas," comprising the principal localities, or regions, where oil and/or gas have been rather generally found. Some of these areas are along rather well defined anticlinal or structural lines; but others completely override the structure and embrace a variety of accumulating conditions. In general, each area has one or more produc-

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[1] V. C. Smith: Oil and Gas Production in Kentucky, Ohio, and West Virginia. *Trans.* A.I.M.E. (1934) **107**, 229–242.

[2] R. Arnold and W. J. Kemnitzer: Petroleum in the United States and Possessions, 157. 1931.

TABLE 1.—*Oil and Gas Production in West Virginia*

Line No.	Producing Area, *County*	Age, Years to End of 1934	Average Depth, Ft.	Producing Rock				Structure[f]	Deepest Zone Tested	
			To Top of Productive Zone	Name	Age[g]	Character[h]	Net Thickness, Average Ft.		Name	Depth of Hole, Ft.
1A	Burning Springs-Volcano, *Wirt, Ritchie, Wood, Pleasants*	74	300	Burning Springs	Pen	S	20	A	Newburg (Sil.)	5720
1B			500	2d Cow Run	Pen	S	50			
1C			600	Salt	Pen	S	50			
1D			800	Big Injun	Mis	S	50			
2	New Cumberland, *Hancock*	70	1200	Berea	Mis	S	15	MC, ML	Berea	1400+
3A	Stillwell-Williamstown, *Wood*	69	700	1st Cow Run	Pen	S	20	H	Gordon	3016
3B			1500	Salt	Pen	S	50			
3C			2200	Berea	Mis	S	15			
4A	St. Marys-Calcutta, *Pleasants*	66	400	1st Cow Run	Pen	S	20	H	Berea	2000
4B			1200	Salt	Pen	S	50			
4C			1300	Maxton	Mis	S	25			
4D			1400	Keener	Mis	S	10			
4E			1425	Big Injun	Mis	S	75			
4F			1900	Berea	Mis	S	20			
5	Wellsburg-Bethany, *Brooke*	52	1650	Berea	Mis	S	20	ML	Berea	1675
6A	Mt. Morris-Mannington, *Monongalia, Marion*	49	1900	Big Injun	Mis	S	150	ML	Elizabeth	3000
6B			2900	Bayard	Dev	S	10			
7A	Cassville-Fairview, *Monongalia, Marion*	45	1600	Big Injun	Mis	S	150	MC, ML	Benson	4700
7B			2000	Berea	Mis	S	50			
7C			2100	Fifty-ft.	Dev	S	50			
7D			2500	Fifth	Dev	S	10			
7E			2600	Bayard	Dev	S	10			
8A	Hundred-Wadestown-Metz, *Wetzel, Monongalia, Marion*	45	1900	Maxton	Mis	S	25	A, AM, S	Elizabeth	3500
8B			2200	Big Injun	Mis	S	200			
8C			2850	Fifty-ft.	Dev	S	50			
8D			3000	Thirty-ft.	Dev	S	20			
8E			3050	Gordon Stray	Dev	S	15			
8F			3100	Gordon	Dev	S	20			
8G			3175	Fourth	Dev	S	15			
8H			3250	Fifth	Dev	S	10			
8I			3300	Bayard	Dev	S	10			
9A	Highland-Cairo-Macfarland-Hartley, *Ritchie, Calhoun*	44	300	Carroll	Pen	S	40	AM, H	Benson	4450
9B			1600	Salt	Pen	S	100			
9C			1700	Keener	Mis	S	25			
9D			1750	Big Injun	Mis	S	50			
9E			1850	Squaw	Mis	S	25			
10A	Sistersville-Middlebourne-McKim, *Tyler*	44	700	1st Cow Run	Pen	S	25	AM, ML, H	Childres	6300
10B			1300	Maxton	Mis	S	25			
10C			1450	Keener	Mis	S	25			
10D			1500	Big Injun	Mis	S	100			
11A	Centerpoint-West Union-Oxford, *Doddridge*	43	1400	Salt	Pen	S	50	A, AM, ML, S	Childres	6667
11B			1600	Maxton	Mis	S	25			
11C			2000	Big Injun	Mis	S	100			
11D			2700	Gordon Stray	Dev	S	10			
11E			2775	Gordon	Dev	S	10			
11F			2850	Fourth	Dev	S	10			
11G			2900	Fifth	Dev	S	10			

[g] Footnotes to column headings and explanation of symbols are on page 249.

TABLE 1.—(*Continued*)

Line No.	Producing Area, *County*	Age, Years to End of 1934	Average Depth, Ft.	Producing Rock				Structure[i]	Deepest Zone Tested	
			To Top of Productive Zone	Name	Age[g]	Character[h]	Net Thickness, Average Ft.		Name	Depth of Hole, Ft.
12A	Wileyville-Uniontown-Littleton, *Wetzel*.....................	42	2200	Big Injun		S	250	A, AM, ML, S	Bayard	3597
12B			3000	Gordon Stray		S	20			
12C			3050	Gordon		S	25			
12D			3100	Fourth		S	20			
13A	Smithfield-Folsom, *Wetzel*.......	42	2100	Big Injun	Mis	S	200	AM, ML, S	Bayard	3044
13B			2850	Gordon Stray	Dev	S	10			
13C			2900	Gordon	Dev	S	20			
14	Big Moses-Wilbur, *Tyler*........	40	1800	Big Injun	Mis	S	150	A	Hamilton	6300
15A	Fink-Newberne-Yellow Creek-Richardson, *Harrison, Lewis, Doddridge, Ritchie, Calhoun*....	40	1800	Maxton	Mis	S	25	MC, S	Elizabeth	3200
15B			2100	Big Injun	Mis	S	150			
15C			2500	Berea	Mis	S	25			
15D			2800	Gordon	Dev	S	15			
16A	Jacksonburg-Stringtown, *Wetzel, Tyler*.....................	38	1850	Keener	Mis	S	25	H	Elizabeth	3037
16B			1900	Big Injun	Mis	S	150			
16C			2650	Gordon Stray	Dev	S	10			
16D			2700	Gordon	Dev	S	20			
17A	Cameron-St. Joseph, *Marshall*...	38	1800	Big Injun	Mis	S	250	A, AM, ML	Childres	4500
17B			2450	Gordon Stray	Dev	S	10			
17C			2500	Gordon	Dev	S	20			
18A	Salem-Wallace, *Harrison*........	35	2200	Big Injun	Mis	S	100	S	Elizabeth	3362
18B			2750	Fifty-ft.	Dev	S	50			
18C			2850	Thirty-ft.	Dev	S	25			
18D			2950	Gordon Stray	Dev	S	30			
18E			3000	Gordon	Dev	S	30			
19A	Kelly-Leopold (Stout), *Doddridge*	35	1800	Big Injun	Mis	S	100	ML	Fifth	3102
19B			2200	Berea	Mis	S	25			
19C			2500	Gordon	Dev	S	5			
20A	Marshville—Wolf Summit—Big Isaac, *Harrison, Doddridge*....		1900	Gordon Stray	Dev	S	30	A, ML	Speechley	3700
20B			2600	Gordon	Dev	S	25			
20C			2700	Fifth	Dev	S	10			
20D			3600	Speechley	Dev	S	10			
21A	Spencer-Flat Fork-Gay, *Roane, Jackson*....................	35	1600	Salt	Pen	S	200	A, S	Trenton	9104
21B			2400	Berea	Mis	S	20			
22A	Kermit-Breeden-Chapmanville, *Mingo, Wayne, Logan*.........	35	600	1st Salt	Pen	S	250	A, Af, ML	Corniferous	3652
22B			1000	2d Salt	Pen	S	35			
22C			1075	Breeden	Pen	S	50			
22D			1200	Maxton	Mis	S	25			
22E			1300	Big Lime	Mis	LS	200			
22F			1500	Keener	Mis	SH	10			
22G			1550	Big Injun	Mis	S	35			
22H			2100	Berea	Mis	S	15			
22I			2900	Childres	Dev	H	100+			
23A	Copley-Sand Fork, *Lewis, Gilmer*	34	2500	Gordon Stray	Dev	S	15	S	Fifth	3276
23B			2550	Gordon	Dev	S	15			
23C			2700	Fifth	Dev	S	15			

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[a] Footnotes to column headings and explanation of symbols are on page 249.

TABLE 1.—(*Continued*)

Line No.	Producing Area, *County*	Age, Years to End of 1934	Average Depth, Ft.	Producing Rock				Structure[f]	Deepest Zone Tested	
			To Top of Productive Zone	Name	Age[g]	Character[h]	Net Thickness, Average Ft.		Name	Depth of Hole, Ft.
24	Rosedale-Eden, *Braxton, Gilmer, Calhoun*	33	1350 1500	Rosedale Gas Rosedale Salt	Pen Pen	S S	75 50	MC	Bayard	2668
25A	Stumptown-Millstone, *Gilmer, Calhoun*	33	1400	Salt	Pen	S	50	A, MC, ML	Elizabeth	2800
25B			1700	Big Injun	Mis	S	50			
25C			2000	Berea	Mis	S	25			
25D			2200	Fifty-ft.	Dev	SH	25			
26A	Milton-Hamlin-Griffithsville, *Cabell, Lincoln*	31	1000	Salt	Pen	S	300	MC	Clinton	4850
26B			1400	Big Lime	Mis	LS	100			
26C			1500	Beckett	Mis	S	50			
26D			2200	Berea	Mis	S	25			
26E			3000	Childres	Dev	H	300			
27	Craddock, *Upshur*	29	1300	Weir	Mis	S	50	MC	Benson	5038
28	Walton-Clover Run, *Roane*	27	1700	Big Injun	Mis	S	50	ML	Berea	2500
29A	Belleville-Lee Creek, *Wood*	27	1900	Berea	Mis	S	20	H	Tully	4092
29B			3800	Childres	Dev	H	250			
30A	Branchland-East Lynn-Wayne-Dunlow, *Lincoln, Wayne*	26	900	Breeden	Pen	S	50	A, AM, ML, MC	Red Medina (Queenston)	4303
30B			1100	Big Lime	Mis	LS	200			
30C			1300	Big Injun	Mis	S	25			
30D			1900	Berea	Mis	S	20			
30E			2700	Childres	Dev	H	300			
30F			3800	Newburg	Sil	LS	15			
31A	Charleston-Clendenin-Clay, *Kanawha, Clay*	25	1400	Big Lime	Mis	LS	150	A, AM, ML, MC	Oriskany	4950
31B			1550	Big Injun	Mis	S	50			
31C			1650	Squaw	Mis	S	25			
31D			1800	Weir	Mis	S	50			
31E			3800	Childres	Dev	H	300			
31F			4800	Oriskany	Dev	S	25			
32A	Shinnston-Clarksburg-Weston, *Harrison, Lewis*	25	1400	Big Injun	Mis	S	100	A, AM, ML, MC, S	Childres	6800
32B			1700	Berea	Mis	S	25			
32C			1775	Gantz	Dev	S	25			
32D			1850	Fifty-ft.	Dev	S	50			
32E			1950	Thirty-ft.	Dev	S	20			
32F			2025	Gordon Stray	Dev	S	15			
32G			2100	Gordon	Dev	S	20			
32H			2175	Fourth	Dev	S	15			
32I			2250	Fifth	Dev	S	20			
32J			3000	Speechley	Dev	S	15			
32K			4200	Benson	Dev	S	10			
33A	Bridgeport-Pruntytown-Samaria, *Harrison, Marion*	25	1300	Big Injun	Mis	S	100	A, AM, ML, MC, S	Salina	7579
33B			1750	Fifty-ft.	Dev	S	50			
33C			1850	Thirty-ft.	Dev	S	20			
33D			2200	Fifth	Dev	S	15			
33E			2300	Bayard	Dev	S	10			
33F			2900	Speechley	Dev	S	15			
33G			4100	Benson	Dev	S	10			

[e] Footnotes to column headings and explanation of symbols are on page 249.

TABLE I.—(*Continued*)

Line No.	Producing Area, County	Age, Years to End of 1934	Average Depth, Ft.	Producing Rock				Structure^i	Deepest Zone Tested	
			To Top of Productive Zone	Name	Age^g	Character^h	Net Thickness, Average Ft.		Name	Depth of Hole, Ft.
34A	Frenchton-Walkersville, *Upshur, Lewis*	25	1500	Big Injun	Mis	S	100	MC	Kane	4665
34B			1650	Squaw	Mis	S	25			
34C			1900	Fifty-ft.	Dev	S	40			
34D			2000	Thirty-ft.	Dev	S	20			
34E			2100	Gordon Stray	Dev	S	15			
34F			2200	Gordon	Dev	S	20			
34G			2275	Fourth	Dev	S	15			
34H			2500	Elizabeth	Dev	S	10			
34I			4200	Benson	Dev	S	10			
35A	Roanoke-Burnsville-German, *Lewis, Braxton*	22	1300	Salt	Pen	S	100	A, AM, MC, ML	Elk	5020
35B			1600	Maxton	Mis	S	25			
35C			1800	Big Injun	Mis	S	150			
35D			2000	Weir	Mis	S	25			
35E			2100	Berea	Mis	S	10			
35F			2200	Fifty-ft.	Dev	S	40			
35G			2300	Thirty-ft.	Dev	S	20			
35H			2400	Gordon Stray	Dev	S	20			
35I			2475	Gordon	Dev	S	20			
36A	Racine-Madison, *Boone*	22	1200	Big Lime	Mis	LS	200	A, AM, MC	Oriskany	4510
36B			1900	Berea	Mis	S	20			
37	Cabin Creek-Joes Creek, *Kanawha, Boone*	20	2500	Berea	Mis	S	35	MC	Berea	3282
38A	Overfield-Johnstown, *Barbour, Harrison*	19	1850	Fifty-ft.	Dev	S	50	AM, MC, H	Benson	4558
38B			3800	Riley	Dev	S	10			
38C			4100	Benson	Dev	S	10			
39A	Baldwin-Glenville-Normantown, *Gilmer*	18	1000	Salt	Pen	S	100	A, AM, MC, ML	Elk	5640
39B			1200	Maxton	Mis	S	25			
39C			1400	Big Injun	Mis	S	50			
39D			1700	Berea	Mis	S	25			
40A	Jarrolds Valley-Prenter, *Raleigh, Boone*	15	1800	Maxton	Mis	S	50	ML, MC, S	Oriskany	6117
40B			2200	Big Lime	Mis	LS	300			
40C			2550	Weir	Mis	S	100			
41	Sandy Summit, *Roane, Jackson, Wirt*	15	2500	Berea	Mis	S	20	MC	Berea	2600
42A	Ethel-Clothier, *Logan, Boone*	13	1300	Salt	Pen	S	100	MC	Salina	5958
42B			2000	Maxton	Mis	S	30			
42C			2200	Big Lime	Mis	LS	200			
42D			2900	Berea	Mis	S	20			
43A	Pineville-McGraw-Slab Fork, *Wyoming, Raleigh*	13	1200	Princeton	Mis	S	50	A, MC	Chemung, Portage	4042
43B			2400	Big Lime	Mis	LS	400			
44A	Huntington-Barboursville-Sarah-Kenova, *Cabell, Wayne*	10	1100	Salt	Pen	S	100	S	Clinton	3805
44B			1500	Big Lime	Mis	LS	150			
44C			2300	Berea	Mis	S	15			
44D			3100	Childres	Dev	H	250			

^g Footnotes to column headings and explanation of symbols are on page 249.

TABLE I.—(*Continued*)

Line No.	Producing Area, *County*	Age, Years to End of 1934	Average Depth, Ft.	Producing Rock				Structure[j]	Deepest Zone Tested	
			To Top of Productive Zone	Name	Age[g]	Character[h]	Net Thickness, Average Ft.		Name	Depth of Hole, Ft.
45A	Pratt-Winifrede, *Kanawha*	10	1500	Big Lime	Mis	LS	200	A, AM, S	Salina	5595
45B			1800	Squaw	Mis	S	40			
45C			1950	Weir	Mis	S	50			
45D			2100	Berea	Mis	S	25			
46A	Hookersville-Muddlety, *Nicholas*	10	800	Salt	Pen	S	100	D, MC	Speechley	4348
46B			1500	Maxton	Mis	S	30			
46C			1700	Big Lime	Mis	LS	75			
46D			1800	Big Injun	Mis	S	150			
47A	Delbarton-Lenore, *Mingo*	10	1600	Big Lime	Mis	LS	175	A, MC, S	Red Clinton	4848
47B			1800	Big Injun	Mis	S	100			
47C			3800	Newburg	Sil	LS				
48A	Bozoo, *Monroe, Summers*	5	600	Indian Mills	Mis	S	80	A	Chemung	3522
48B			2800	Squaw	Mis	S	100			
48C			3000	Weir	Mis	S	225			
49	Cottageville, *Jackson*	3	3800	Childres	Dev	H	150	S	Tully	4038
50A	Welch-Elbert, *McDowell*	1	50–500	Pocohontas	Pen	S	?			
50B			3900	Berea	Mis	S	40	MC	Oriskany	6639

Area Proved, Acres (Figures by Smith)		Total Oil Production, Bbl.			Average Barrels per Well Daily, November, 1934
Oil	Gas	To End of 1934	During 1933	During 1934	
578,750	990,550	391,356,000	3,827,000	4,087,000	0.58

Total Gas Production, Millions Cu. Ft.			Number of Oil and/or Gas Wells			
To End of 1934	During 1933	During 1934	Completed to End of 1934	Completed during 1934	At End of 1934	
					Producing Oil Only	Producing Gas Only
5,786,705	95,607	95,000±	60,000±	458	18,850±	12,700±

[g] Footnotes to column headings and explanation of symbols are on page 249.

tive sands and possibly several types of accumulation. Where several productive sands are noted a single well may produce from only one or possibly from three or four zones, but seldom from the entire list. Depths of sand may vary considerably throughout each area. Age of development is necessarily set as the first significant discovery, regardless of later enlargements, which may have caused extensive redrilling.

Table 2.—*Summary of Drilling Operations in West Virginia*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1935											Completed during 1934						Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes										Productive Wells	Dry and/or Near-dry Holes					Productive Wells		
	Total Depths, Ft.											Total Depths, Ft.							
	0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000	9,000–10,000	Total	(For Details See Table 1)	0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	Total	(For Details See Table 1)	Within Fields	Exploratory
Barbour	6	3	5	3	8	1	0	0	0	26	25	0	0	0	0	0	0	0	0
Berkeley	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boone	x	x	x	x	1	0	1	0	0	x	x	0	0	1	1	2	31	3	0
Braxton	x	x	x	x	0	0	0	0	0	x	x	0	0	0	0	0	0	1	0
Brooke	x	x	x	x	0	0	0	0	0	x	x	0	1	0	0	1	0	1	0
Cabell	x	x	x	x	1	0	0	0	0	x	x	0	1	2	0	3	28	x	0
Calhoun	x	x	x	x	0	0	0	0	0	x	x	0	10	2	0	12	56	16	0
Clay	x	x	x	x	1	0	0	0	0	x	x	0	0	0	0	0	5	1	0
Doddridge	x	x	x	x	0	0	0	0	0	x	x	0	1	1	0	2	6	1	0
Fayette	0	2	11	5	0	1	0	0	0	19	12	0	0	0	0	0	0	0	0
Gilmer	x	x	x	x	x	1	0	0	0	x	x	0	2	8	0	10	35	4	0
Grant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greenbrier	0	1	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Hampshire	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Hancock	x	x	x	0	0	0	0	0	0	x	x	0	0	0	0	0	1	0	0
Hardy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harrison	x	x	x	x	x	x	x	1	0	x	x	0	0	0	0	0	2	1	0
Jackson	x	x	x	x	0	0	0	0	0	x	x	0	1	0	0	1	0	0	0
Jefferson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kanawha	x	x	x	x	1	1	0	0	0	x	x	0	0	1	0	1	18	12	0
Lewis	x	x	x	x	x	0	0	0	0	x	x	1	0	0	0	1	0	0	0
Lincoln	x	x	x	x	x	1	0	0	0	x	x	0	0	0	1	1	9	1	0
Logan	1	7	26	8	2	1	0	0	0	45	83	0	0	0	0	0	1	1	0
McDowell	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	20	x	x
Marion	x	x	x	x	x	0	0	1	0	x	x	0	0	0	1	1	5	3	1
Marshall	x	x	x	x	x	0	0	0	0	x	x	0	0	0	0	0	9	2	0
Mason	4	19	5	1	3	0	0	0	0	32	9	0	0	0	0	0	0	1	0
Mercer	0	1	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0
Mineral	1	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Mingo	0	13	15	2	0	0	0	0	0	30	146	0	0	0	0	0	1	0	0
Monongalia	x	x	x	x	1	1	0	0	0	x	x	0	0	0	2	2	9	0	0
Monroe	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Morgan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nicholas	3	2	20	4	0	0	0	0	0	29	38	0	0	0	0	0	1	0	0
Ohio	x	x	x	x	1	0	0	0	0	x	x	0	0	0	0	0	0	0	0
Pendleton	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Pleasants	x	x	x	x	0	0	0	0	0	x	x	3	2	0	0	5	9	5	0
Pocahontas	1	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Preston	7	9	1	3	1	0	0	0	0	22	0	0	0	0	0	0	0	0	0
Putnam	x	x	x	x	1	0	0	0	0	x	x	0	0	0	0	0	4	1	0
Raleigh	x	1	1	4	2	0	0	0	0	8	12	0	0	0	0	0	0	2	0
Randolph	0	1	2	0	2	1	0	0	0	6	0	0	0	0	0	0	0	0	0
Ritchie	x	x	x	x	2	0	0	0	0	x	x	0	20	12	0	32	122	9	0
Roane	x	x	x	x	0	0	0	0	1	x	x	0	3	1	0	4	34	4	0
Summers	1	2	2	2	1	0	0	0	0	8	1	0	0	0	0	0	0	0	0
Taylor	1	6	13	3	1	0	0	0	0	24	23	0	0	0	0	0	0	0	0
Tucker	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Tyler	x	x	x	x	1	0	1	0	0	x	x	1	8	0	0	9	7	2	0
Upshur	2	7	13	1	2	0	0	0	0	24	50	0	0	0	0	0	3	1	0
Wayne	x	x	x	x	1	0	0	0	0	x	x	0	0	0	0	0	11	0	0
Webster	1	3	2	1	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
Wetzel	x	x	x	x	x	0	0	0	0	x	x	0	0	2	1	3	10	2	0
Wirt	x	x	x	x	0	0	0	0	0	x	x	2	1	0	0	3	15	3	0
Wood	x	x	x	x	2	1	0	0	0	x	x	0	2	0	0	2	6	1	0
Wyoming	0	0	0	1	0	0	0	0	0	1	7	0	0	0	0	0	0	0	0
Total																			

If necessary, the list of producing areas might be somewhat enlarged by inclusion of minor isolated discoveries that have no great present significance. Such areas may properly remain unlisted until more extensive drilling proves or disproves their worth.

In Table 2 all counties of the state, including four that have had no tests, are listed, with such details regarding dry holes and productive wells as may be prudently furnished. In 27 counties, where production is more or less general, no details are given except with regard to the deeper exploratory tests. In 22 counties, where drilling is scattered or new, the information is fairly, or in some instances, entirely definite and actual figures may be used with reasonable certainty.

In the earlier review by Smith[3], the attempt is made to classify all the drilling of the state by counties and depth of hole, resulting in a figure of 51,698 ± wells and a further estimate that "more than 65,000 oil and/or gas wells, including nonproductive wells, have been drilled in West Virginia." Arnold and Kemnitzer[4] give a figure of 57,597 wells drilled from 1860 to 1928. These varying figures illustrate the futility

TABLE 3.—*Summary of New Production*

County	Wells Drilled	Oil		Gas		Dry
		Number of Wells	Bbl. per Day	Number of Wells	M. Cu. Ft. per Day	
Boone	33	3	20	28	19,631	2
Brooke	1	0		0		1
Cabell	31	0		28	17,069	3
Calhoun	68	18	191	38	11,066	12
Clay	5	2	20	3	418	0
Doddridge	8	3	13	3	4,200	2
Gilmer	45	12	1,366	23	11,865	10
Hancock	1	1	2	0		0
Harrison	2	2	2	0		0
Jackson	1	0		0		1
Kanawha	19	2	210	16	9,215	1
Lewis	1	0		0		1
Lincoln	10	0		9	1,414	1
Logan	1	0		1	100	0
Marion	6	3	37	2	188	1
Marshall	9	4	31	5	1,526	0
McDowell	20	0		20	500	0
Mingo	1	0		1	200	0
Monongalia	11	5	55	4	1,338	2
Nicholas	1	0		1	100	0
Pleasants	14	4	33	5	640	5
Putnam	4	0		4	764	0
Ritchie	154	79	3,546	43	17,414	32
Roane	38	17	171	17	13,619	4
Tyler	16	7	15	0		9
Upshur	3	0		3	1,500	0
Wayne	11	7	23	4	915	0
Wetzel	13	2	31	8	4,900	3
Wirt	18	7	9	8	5,816	3
Wood	8	6	17	0		2
Totals	553	184	5,792	274	124,398	95

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[3] Reference of footnote 1.

[4] Reference of footnote 2, 166.

of any attempt to give positive statistics on the older producing counties, although the researches of Mr. Smith and his organization are known to have been extensive and are well worthy of serious consideration.

In Table 3 is a summary of new production for 1934 as gathered from trade journal reports.

TABLE 4.—*Summary of Tests to Corniferous Lime and Deeper Formations in West Virginia*

County	Number of Wells	Corniferous Lime			Oriskany Sand			Newburg Sand			"Clinton" Sand		
		Oil	Gas	Dry	Oil	Gas	Dry	Oil	Gas	Dry	Oil	Gas	Dry
Boone	2	0	0	2	0	0	2	—	—	—	—	—	—
Cabell	2	0	0	2	0	0	2	0	0	1	0	0	1
Hampshire	1	0	0	1	0	0	1	—	—	—	—	—	—
Harrison	1	0	0	1	—*	—	—	—	—	—	—	—	—
Kanawha	8	0	0	8	1	5	2	—	—	—	—	—	—
Lincoln	1	0	0	1	0	0	1	0	0	1	—	—	—
Logan	2	0	0	2	0	0	2	—	—	—	—	—	—
McDowell	1	0	0	1	0	0	1	—	—	—	—	—	—
Marion	1	0	0	1	0	0	1	—	—	—	—	—	—
Mason	6	0	0	6	0	0	1	0	0	1	0	0	1
Mineral	1	0	0	1	0	0	1	—	—	—	—	—	—
Mingo	3	0	0	3	0	0	3	0	1	1	—	—	—
Pendleton	1	0	0	1	0	0	1	—	—	—	—	—	—
Putnam	3	0	0	3	0	0	3	—	—	—	—	—	—
Randolph	1	0	0	1	0	0	1	0	0	1	0	0	1
Roane	1	0	0	1	0	0	1	0	0	1	0	0	1
Tucker	1	0	0	1	0	0	1	—	—	—	—	—	—
Wayne	6	0	0	6	0	0	6	0	3	0	0	0	3
Wood	3	0	0	3	1	1	2	0	0	1	—	—	—
Totals	45	0	0	45	2	6	32	0	4	7	0	0	7

* Dashes indicate that the formation was not reached.

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Oil Development and Production in Wyoming in 1934

By John G. Bartram*

(New York Meeting, February, 1935)

The oil business has been relatively quiet in Wyoming during 1934. Only 34 producing wells were completed, 54 dry holes were drilled, and at the end of the year only 30 wells are listed as drilling. Wyoming still has a large reserve of production shut in, mostly in black oil or asphaltic base fields in the northwestern part of the state.

The total oil production increased from 11,171,500 bbl. in 1933 to 12,539,470 in 1934, but light oil production continued to decline, and the increase was made by black oil fields. This is partly due to natural decline of light oil fields, especially Salt Creek, Big Muddy and Lost Soldier, but largely because of increased demands for road oil. The Rocky Mountain states spent much money to build and improve roads and a greater amount of road oil was used. The refining of black oil to manufacture road oil produced gasoline as a byproduct that slightly decreased the demand for light oil. The Oregon Basin and Frannie fields, in the Big Horn Basin, moved into second and third places in the list of producing fields in Wyoming because of their increased black oil production, and Big Muddy and Lost Soldier, light oil fields, dropped back. Wyoming stayed close to its allowed production, which was based on the needs of the refiners and purchasers.

This activity in black oil resulted in a few more wells in the fields of the Big Horn Basin, but the greatest amount of drilling was in the shallow Osage field in eastern Wyoming. Osage supplies many little topping plants and at the close of 1934 there was not enough oil available there to supply all of them. In the Lost Soldier field and Salt Creek, one major company was rather active in a campaign to deepen, clean out and repair old wells to increase production, and the figures of that work are not included here. Of the light oil fields, Lance Creek promises to be most active during 1935, since the two wells in the recently discovered Sundance sand pool are producing and more wells will be drilled.

With wildcatting almost at a standstill, two new oil fields were discovered in Wyoming in 1934. In Albany County, a 75-bbl. oil well was completed on Quealey dome in the Muddy sand (Upper Cretaceous)

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Table 1.—*Oil and Gas Production in Wyoming*

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934
1	Alkali Butte, *Fremont*	6	40		300	300	8,130	0	0	0
2	Allen Lake, *Carbon*	1	0	0	200	200				
3	Ant Hills, *Niobrara*	7	40	0	0	40	7,378	0	0	0
4	Badger Basin, *Park*	4	200	0	0	200	60,350	16,700	14,650	40
	Baxter Basin, *Sweetwater*									
5	Frontier	12			7,467	7,467				
6	Dakota	12			4,310	4,310				
7	Total	12			7,467	7,467				
	Big Muddy, *Converse*									
8	Shannon	18	2,000			2,000	1,*xxx*,*xxx*	*x*	*x*	*x*
9	Wall Creek	18	2,600			2,600	22,*xxx*,*xxx*	60*x*,*xxx*	58*x*,*xxx*	1,590
10	Dakota	12	400			400	47*x*,*xxx*	42,000	4*x*,*xxx*	110
11	Total	18	2,600			2,600	23,683,000	647,000	628,000	1,700
	Big Sand Draw, *Fremont*									
12	Wall Creek	17			1,200	1,200				
13	Morrison	4			300	300				
14	Total	17			1,200	1,200				
15	Billy Creek, *Johnson*	13			700	700				
16	Black Mountain, *Hot Springs*									
	Embar	9	60			60	26,*xxx*	0	22,*xxx*	0
17	Tensleep	11	300			300	32,*xxx*	0	26,*xxx*	0
18	Total	11	360			360	68,500	0	48,600	0
	Bolton Creek, *Natrona*									
19	Sundance	14	50			50	3*x*,*xxx*	0	0	0
20	Embar	14	50			50	1*x*,*xxx*	0	0	0
21	Total	14	50			50	45,640	0	0	0
22	Boone, *Natrona*	14			300	300				
	Byron (East Byron), *Big Horn*									
23	Frontier	12±			500	500				
24	Sundance	5	40			40	14,000	0	0	0
25	Tensleep	2	600			600	157,000	9,000	111,000	420
26	Total	12±	600		500	600	171,000	9,000	111,000	420
27	Circle, *Fremont*	11	250			250	0	0	0	0
28	Dallas-Derby, *Fremont*	51	350			350	1,876,500	151,000	218,500	810
29	Dutton Creek, *Carbon*	8								
30	Shannon	8			800	800				
31	Muddy	8	150			150	160,200	24,300	27,200	68
32	Total	8	150		800	800	160,200	24,300	27,200	68
	East Mahoney, *Carbon*									
33	Dakota	13			3,100	3,100				
34	Sundance	9			3,500	3,500				
35	Total	13			3,500	3,500				
36	Eight Mile Lake, *Carbon*	11			250	250				
	Elk Basin, *Park*									
37	Frontier	19	580			580	10,250,600	212,000	201,600	400
38	Dakota	13			1,200	1,200				
39	Total	19	580		1,200	1,200	10,250,600	212,000	201,600	400
40	Enos Creek, *Hot Springs*	11			500	500				
41	Ferris, *Carbon*	17		200		200	468,920	6,950	7,120	14
42	Fourbear, *Park*	6	500			500	0	0	0	0
	Frannie, *Park*									
43	Tensleep	6	640			640	1,296,400	77,500	622,400	2,155
44	Madison	5	10			10	70,000	9,000	6,000	15
45	Total	6	650			650	1,366,400	86,500	628,400	2,170
	Garland, *Big Horn*									
46	Frontier	27	40			40	340,000	0?	0?	0?
47	Dakota	15			1,200	1,200				
48	Embar-Tensleep	7			1,650	1,650				
49	Madison	3	960			960	742,000	172,700	249,000	420
50	Total	27	960		1,650	1,650	1,082,000	172,700	249,000	420
51	Golden Eagle, *Hot Springs*	15			120	120				
	Grass Creek, *Hot Springs*									
52	Frontier	20	1,400			1,400	22,794,000	53,900	354,000	1,650
53	Embar-Tensleep	13	900			900	1,284,000	218,000	0	0
54	Total	20	1,400			1,400	24,078,000	271,900	354,000	1,650
55	Greybull, *Big Horn*	26	640			640	244,700	1,850	1,150	5
	Hamilton, *Hot Springs*									
56	Embar	16	640			640	3,337,000	220,000	303,000	790
57	Tensleep	5	300			300	0	0	0	0
58	Total	16	640			640	3,337,000	220,000	303,000	790

[a] Footnotes to column headings and explanation of symbols are on page 249.

TABLE 1.—(*Continued*)

Line Number	Field, County	Age, Years to End of 1934	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934
59	Hidden Dome, *Washakie*	17	60		640	700	10,000[1]	2,500[1]	7,500	20
60	Labarge, *Lincoln, Sublette*	11	950			950	3,851,000	342,000	440,000	1,350
61	Lake Creek, *Hot Springs*	9	100			100	0	0	0	0
	Lance Creek, *Niobrara*									
62	Dakota	12		1,500		1,500	4,264,000	27,500	50,000[1]	150
63	Sundance	4	600			600	71,000	0	71,000[1]	100
64	Total	12	600	1,500		1,500	4,335,000	27,500	121,000	250
	Lander (Hudson), *Fremont*									
65	Embar	16	340			340	650,000	7,000[1]	7,000[1]	10
66	Tensleep	8	110			110	884,000	112,000	101,000	290
67	Total	16	350			340	1,534,000	119,000	108,000	300
68	Little Buffalo Basin, *Hot Springs, Park*	20			4,800	4,800				
69	Little Grass Creek, *Hot Springs*	18			160	160				
70	Little Polecat, *Park*	16			500	500				
	Lost Soldier, *Sweetwater*									
71	Frontier	18	200			200	1,000,000[1]	35,000	120,000	330
72	Dakota-Lakota	12	350			350	12,918,000[1]	343,000	283,000	850
73	Sundance	8	100			100	3,000,000[1]	230,000	270,000	470
74	Tensleep	4	100			100	500,000[1]	0	4,000	0
75	Total	18	350			350	17,418,000	608,000	577,000	1,650
	Mahoney Dome, *Carbon*									
76	Dakota	15			1,400	1,400				
77	Sundance	10			1,660	1,660				
78	Tensleep	5	200			200	0	0	0	0
79	Total	15	200		1,660	1,660	0	0	0	0
80	Maverick Springs, *Fremont*	17	1,400			1,400	0	0	0	0
81	Midway, *Natrona*	4	200			200	128,000	37,500	34,000	65
82	Mule Creek, *Niobrara*									
83	Lakota	14	220			220	1,192,000	400	7,*xxx*	45
84	Minnelusa	4	100			100	2,*xxx*	0	2,*xxx*	40
85	Total	14	220			220	1,194,000	400	9,000	85
86	Muskrat, *Fremont*	7			500	500				
	North Baxter, *Sweetwater*									
87	Frontier	8			100	100				
88	Dakota	7			1,200	1,200				
89	Sundance	7			3,700	3,700				
90	Total	8			3,700	3,700				
91	North Byron, *Park*	19			800	800				
92	North Casper Creek, *Natrona*	4	100			100	1,874	0	0	0
93	North Sunshine, *Park*	7	150			150	0	0	0	0
94	Notches, *Natrona*	12	400			400	170,000	0	0	0
	Oregon Basin, *Park*									
95	Dakota	22			1,300	1,300				
96	Embar-Tensleep	8	10,000			10,000	5,103,000	155,000	798,000	2,700
97	Total	8	10,000		1,300	10,000	5,103,000	155,000	798,000	2,700
98	Osage, *Weston*	14	10,000			10,000	3,142,000	267,000	297,000	730
	Pilot Butte, *Fremont*									
99	Niobrara	18	250			250	512,200	9,500	9,000	33
100	Muddy	5			400	400				
101	Total	18	250		400	650	512,200	9,500	9,000	33
102	Pine Mountain, *Natrona*	15			100	100				
103	Pitchfork, *Park*	4	300			300	0	0	0	0
104	Plunkett, *Fremont*	13	45			45	11,700	0	0	0
105	Poison Spider, *Natrona*	16		400		400	615,000	100,000	108,000	180
106	Powder River, *Natrona*	4			150	150				
107	Quealey, *Albany*	1	100			100	0	0	0	0
108	Rex Lake, *Albany*	11	200			200	213,200	2,600	8,200	55
109	Rock Creek, *Carbon*	17	1,300			1,300	15,440,000	460,000	540,000	1,430
	Salt Creek, *Natrona*									
110	1st Wall Creek	26	4,350			4,350	46,200,000	505,000	450,000	1,350
111	2nd Wall Creek	17	21,450			21,450	193,300,000	5,365,000	5,000,000	13,600
112	Lakota	10	2,030			2,030	14,500,000	745,000	675,000	1,950
113	Sundance	9	660			660	4,560,000	535,000	475,000	1,350
114	Tensleep	4	640			640	65,000	0	0	0
115	Total	26	21,450			21,450	258,650,000	7,150,000	6,600,000	18,250
116	Shannon, *Natrona*	45	200			200	55,400	0	0	0
117	Simpson Ridge, *Carbon*	10	160			160	159,000	0	0	0

[1] Estimated.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934
118	South Casper Creek, *Natrona*	12	240			240	2,055,650	61,000	79,650	620
119	South Sunshine, *Park*	8	300			300	0	0	0	0
120	Spindletop, *Natrona*	6	80			80	0	0	0	0
121	Spring Creek, *Park*	5	250			250	0	0	0	0
122	Spring Valley, *Uinta*	34	400			400	51,500	2,000	2,100	10
	Teapot Dome, *Natrona*									
123	Wall Creek	12	640	2,000		2,640	3,000,000[1]	0	0	0
124	Shale	12	*x*			*x*	678,800[1]	7,600	8,800	20
125	Total	12	640	2,000		2,640	3,678,800	7,600	8,800	20
126	Torchlight, *Big Horn*	19	600			600	96,000	0	0	0
127	Warm Springs, *Hot Springs*	17	200			200	216,150	0	0	0
128	Waugh, *Hot Springs*	1	100			100	0	0	0	0
129	Werts, *Carbon*									
130	Frontier	9			100	100				
131	Dakota	14			500	500				
132	Lakota	7			500	500				
133										
134	Sundance	5			200	200				
135	Total	14			500	500				
136	Total, Wyoming		51,895	4,100	33,897	89,892	370,109,792	11,171,500	12,539,470	36,235

at a depth of 3175 ft. It is considered a seismograph discovery, since the crest of the structure was missed by surface geology and two dry holes drilled before the anticline was "shot." The Muddy sand is fairly thin and the importance of Quealey depends on whether oil will be found also in the Dakota or Lakota sands, 100 to 200 ft. below the Muddy sand. The other discovery was at Waugh dome, in Hot Springs County, on almost the last day of the year. A 600-bbl. well of 28° gravity oil was completed in the Embar lime at 3800 ft. It is an interesting well, especially since it is close to a pipe line, but the structure is well defined on the surface and the pool cannot be very large.

Production practice changed little during 1934. Most of the wells in the state are pumped and relatively few flow. There are probably no wells on gas-lift or air-lift in the state, although several years ago one was used for a time at Lost Soldier. Gas drives have been in use at Salt Creek, Labarge, Elk Basin and Lost Soldier, and perhaps at a few other places, but there has been no attempt to inject air or water into the reservoir rocks.

The natural gas industry was also relatively quiet, with no decided change in field or market conditions. A few wells were drilled in the Baxter Basin area of southwestern Wyoming, to comply with lease obligations and field programs. Some exploratory work was done in southern Wyoming to develop additional reserves for the recently opened gas market at Laramie. Almost no gas wells were drilled in the central and northern parts of the state. The existing pipe lines have ample

TABLE 1.—(*Continued*)

	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1934		At End of 1934				
Line Number	Per Acre to End of 1934[b]	Per Acre-Foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	200	6	0	0	0	0	0	3	0	0	3	0	0	0	0
2				*y*	0	*y*	*y*	3	2	0	0	0	0	3	3
3	180	30	0					1	0	0	1	0	0	0	0
4	300	8	40					1	0	0	0	1	0	0	1
[illegible]				*y*	*y*	*y*	*y*	8	1	0	0	0	0	8	8
[illegible]				*y*	*y*	*y*	*y*	11	0	0	0	0	0	11	11
7				9,400[1]	2,000[1]	2,400[1]	*y*	19	1	0	0	0	0	19	19
8	500	8	*x*					35	0	0	21	14	0	0	14
9	8,450	84	12					134	0	0	4	130	0	0	130
10	1,170	78	27					4	0	0	0	4	0	0	4
11	9,150							173	0	0	25	148	0	0	148
12				36,250[1]	2,250	2,250[1]	*y*	10	0	0	0	0	0	10	10
13				0	0	0	0	1	0	0	1	0	0	0	0
14				36,250[1]	2,250	2,250[1]	*y*	11	0	0	0	0	0	10	10
15				1,330[1]	220	230[1]	*y*	8	0	0	0	0	0	8	8
16	435	12	0					2	0	0	2	0	0	0	0
17	100	1	0					4	0	0	4	0	0	0	0
18	190		0					6	0	0	6	0	0	0	0
19	700	70	0					3	0	0	3	0	0	0	0
20	200	13	0					1	0	0	1	0	0	0	0
21	913		0					4	0	0	4	0	0	0	0
22				3,970[1]	80	70[1]	*y*	4	0	0	2	0	0	2	2
23				2,300[1]	100[1]	100[1]	*y*	2	0	0	0	0	0	2	2
24	350	35	0					1	0	0	1	0	0	0	0
25	262	4	420					2	1	0	0	2	0	0	2
26	284			2,300[1]	100[1]	100[1]	*y*	5	1	0	1	2	0	2	4
27	0	0	0					2	0	0	2	0	0	0	0
28	5,350	36	17					50	0	0	2	48	0	0	48
29															
30				625[1]	125[1]	200[1]		5	0	0	0	0	0	5	5
31	1,000	34	23					3	0	0	0	3	0	0	3
32	1,000			625[1]	125[1]	200[1]	*y*	8	0	0	0	3	0	5	8
33				8,000[1]	10[1]	10[1]	*y*	2	0	0	0	0	0	2	2
34				15,000[1]	200[1]	150[1]	*y*	11	0	0	0	0	0	11	11
35				23,000[1]	210[1]	160[1]	*y*	13	0	0	0	0	0	13	13
36				4,600[1]	40	50[1]		4	0	0	3	0	0	1	1
37	17,900	448	3					149	0	0	1	148			148
38				18,000[1]	1,600	est 1,700	*y*	4	0	0	0			4	4
39	17,900			18,000[1]	1,600	est 1,700	*y*	153	0	0	1	148		4	152
40				0	0	0	0	1	0	0	1	0	0	0	0
41	2,340	94	1.6	*y*	*y*	*y*	*y*	8	0	0	0	8	0	0	8
42	0	0	0					1	0	0	1	0	0	0	0
43	2,030	20	196					11	4	0	8	3	0	0	3
44	7,000	*x*	15					1	0	0	0	1	0	0	1
45	2,100							12	4	0	8	4	0	0	4
46	8,500	240	0					3	0	0	3	0	0	0	0
47				20,000[1]	125[1]	125[1]	*y*	10	0	0	6	0	0	4	4
48				1,300[1]	325[1]	350[1]	*y*	2	0	0	1	0	0	1	1
49	770	4	140					3	0	0	0	2	1	0	3
50	1,120			21,300[1]	450[1]	475[1]	*y*	18	0	0	10	2	1	5	8
51				2,250	0	0	0	0	0	0	0	0	0	0	0
52	16,300	80	5					316	0	0	11	305	0	0	305
53	1,420	7	0					11	0	0	11	0	0	0	0
54	17,300							327	0	0	22	305	0	0	305
55	380	19	3					14	0	0	6	8	0	0	8
56	5,200	104	27					29	2	0	0	29	0	0	29
57	0	0	0					1	0	0	1	0	0	0	0
58	5,200							30	2	0	1	29	0	0	29
59	150	*x*	10	24,000	0	0	0	7	2	0	5	2	0	0	2
60	4,050	27	20					102	1	0	31	70	0	0	70
61	0	0	0					1	0	0	1	0	0	0	0
62	2,840	40	30	58,000[1]	2,750[1]	1,600[1]	*x*	14	0	0	0	5	0	9	14
63	120	7	50					2	0	0	0	2	0	0	2
64	2,900		36	58,000[1]	2,750[1]	1,600	*x*	16	0	0	0	7	0	9	16
65	1,900	32	5					31	0	0	29	2	0	0	2
66	8,000	63	56					5	0	0	0	5	0	0	5
67	4,500							36	0	0	29	7	0	0	7
68				12,100[1]	715	725[1]	*y*	10	0	0	2	0	0	8	8
69				1,100[1]	125	125[1]	*y*	2	0	0	1	0	0	1	1

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1934		At End of 1934				
	Per Acre to End of 1934[b]	Per Acre-Foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
70				400[1]	100[1]	100[1]	*y*	1	0	0	0	0	0	1	1
71	5,000[1]	50	11					29	0	0	0	29	0	0	29
72	37,000[1]	460	34					27	0	0	2	25	0	0	25
73	30,000	150	94					5	0	0	0	5	0	0	5
74	5,000	76	0					1	0	0	1	0	0	0	0
75	49,765		28					62	0	0	3	59	0	0	59
76				14,200[1]	12[1]	10[1]	*y*	1	0	0	0	0	0	1	1
77				40,200[1]	1,500[1]	1,000[1]	*y*	9	0	0	0	0	0	9	9
78	0	0	0					1	0	0	1	0	0	0	0
79	0	0	0	54,400[1]	1,512[1]	1,010[1]	*y*	11	0	0	1	0	0	10	10
80	0	0	0					32	0	0	32	0	0	0	0
81	640	21	65					3	1	0	2	1	0	0	1
82															
83	5,430	214	3					37	0	0	19	18	0	0	18
84	20	1	40					1	0	0	0	1	0	0	1
85	5,450							38	0	0	19	19	0	0	19
86				2,325[1]	640	425[1]	*y*	1	0	0	1	0	0	0	0
87								0	0	0	0	0	0	0	0
88								3	1	0	0	0	0	3	3
89								2	0	0	0	0	0	2	2
90				3,600[1]	1,000[1]	1,500[1]	*y*	5	1	0	0	0	0	5	5
91				8[1]	2[1]	3[1]	*y*	4	0	0	3	0	0	1	1
92	19	4	0					2	0	0	2	0	0	0	0
93	0	0	0					1	0	0	1	0	0	0	0
94	425	100	0					3	0	0	3	0	0	0	0
95				1,125[1]	125[1]	125[1]		4	1	0	0	0	0	4	4
96	510	3	180					34	3	0	19	15	0	0	15
97	510			1,125[1]	125[1]	125[1]	*y*	38	4	0	19	15	0	4	19
98	314	31	2					399	13	*y*	9	390	0	0	390
99	2,050	*x*	3					11	1	0	0	11	0	0	11
100				0	0	0	0	2	0	0	2	0	0	0	0
101	2,050	*x*		0	0	0	0	13	1	0	2	11	0	0	11
102				0	0	0	0	2	0	0	2	0	0	0	0
103	0	0	0					1	0	0	1	0	0	0	0
104	260	*x*	0					0	0	0	0	0	0	0	0
105	1,540	44	12	5,600	0	0	0	17	0	0	2	15	0	0	15
106				0	0	0	0	1	0	0	1	0	0	0	0
107	0	0	0					1	1	0	1	0	0	0	0
108	1,066	21	14					4	0	0	0	4	0	0	4
109	11,875	108	30					65	0	0	17	48	0	0	48
110	10,600	96	3.5					384	0	12	0	384	0	0	384
111	9,010	138	8.7					1,565	0	42		1,565	0	0	1,565
112	7,140	350	25					78	0	35	0	78	0	0	78
113	7,000	100	30					45	0	2	0	45	0	0	45
114	100	1	0					1	0	0	1	0	0	0	0
115	12,500							2,073	0	91	1	2,072	0	0	2,072
116	277	4	0					0	0	0	0	0	0	0	0
117	1,000	25	0					0	0	0	0	0	0	0	0
118	856	6	36	11,292	0	0	0	17	0	0	16	1	0	0	1
119	0	0	0					1	0	0	1	0	0	0	0
120	0	0	0					3	0	0	3	0	0	0	0
121	0	0	0					1	0	0	1	0	0	0	0
122	130	*x*	1					29	0	0	18	11	0	0	11
123	4,700	117	0		0	0	0	47	0	0	47	0	0	0	0
124	*x*	*x*	10					15	0	0	13	2	0	0	2
125	1,400			4,500	0	0	0	62	0	0	60	2	0	0	2
126	160	3	0					0	0	0	0	0	0	0	0
127	1,080	16	0					37	0	0	37	0	0	0	0
128	0	0	0					1	1	0	1	0	0	0	0
129															
130				700	0	0	*y*	0	0	0	0	0	0	0	0
131				33,000[1]	450	400[1]	*y*	3	0	0	0	0	0	3	3
132				20,500[1]	2,600	2,400[1]	*y*	2	0	0	0	0	0	2	2
133															
134				1,200[1]	0	0	*y*	1	0	0	0	0	0	1	1
135				55,400[1]	3,050	2,800[1]	*y*	6	0	0	0	0	0	6	6
136			10.5	356,875	17,094	16,048	*y*	3,986	34	91	428	3,440	1	115	3,556

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1934			Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1934				
			Number of Wells				Average at End of		Gravity A.P.I. at 60° F.				
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas Lift	Initial	1933	1934	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	4,600	4,570		1	0	*y*	*y*	*y*	*x*	*x*	36	0	M
2	2,175	2,100				*y*	*y*	*y*					
3	3,957	3,951	0	0	0	*x*	*x*	*x*	*x*	*x*	36	0.1	M
4	8,500	8,250	0	1	0	*x*	*x*	*x*	*y*	*y*	48	0	P
5	2,400	2,350				800	*y*	*y*					
6	3,000	2,950				775	*y*	*y*					
7													
8	1,250	1,200	0	35	0	*x*	*x*	*x*	*y*	*y*	31	*y*	M
9	3,400	3,260	0	134	0	*x*	*x*	*x*	*y*	*y*	32	0.17	M
10	4,700	4,600	2	2	0	*x*	*x*	*x*	*y*	*y*	36	0.18	M
11			2	171	0								
12	2,800	2,300				1,100–1,300	*y*	*y*					
13	4,350	4,300				*x*	*x*	*x*					
14													
15	3,250	3,200				1,150	*y*	*y*					
16	2,950	2,900	0	2	0	*x*	*x*	*x*	*y*	*y*	25	2.8	A
17	3,350	3,170	0	4	0	*x*	*x*	*x*	*y*	*y*	23	2.9	A
18			0	6	0	*x*							
19	1,120	1,100	0	3	0	*x*	*x*	*x*	*x*	*x*	22	2.8	A
20	2,050	2,025	0	1	0	*x*	*x*	*x*	*x*	*x*	32	3.0	A
21			0	4	0	*x*							
22	2,200	2,150				*y*	*y*	*y*					
23	2,500	2,400				1,000[1]	*y*	*y*					
24	4,209	4,205	0	1	0	*x*	*x*	*x*	*x*	*x*	32	0.38	M
25	5,400	5,300	0	2	0	*y*	*y*	*y*	*y*	*y*	25	2.2	A
26			0	3	0								
27	655	170	0	2	0	*x*	*x*	*x*	*x*	*x*	23	*y*	A
28	1,200	700	0	50	0	*x*	*x*	*x*	*y*	*y*	23	2.4	A
29													
30	1,700	1,600				450	*y*	*y*					
31	4,900	4,850	0	3	0	*x*	*x*	*x*	*y*	*y*	34	0.3	M
32													
33	2,300	2,200				700	*y*	*y*					
34	2,700	2,600				1,140	*y*	*y*					
35													
36	3,500	3,400				1,600	*y*	*y*					
37	1,200	1,000	0	148	0	*x*	*x*	*x*	*y*	*y*	43	0.14	P
38	2,500	2,400				925	*y*	*y*					
39			0	148	0								
40	2,850	2,600				790	*x*	*x*					
41	1,650	1,600	0	8	0	*y*	*y*	*y*	*y*	*y*	36	0.45	M
42	3,350	3,270	0	0	0	*y*	*y*	*y*	*x*	*x*	15	*y*	A
43	2,800	2,770	0	11	0	*x*	*x*	*x*	*y*	*y*	28	2.5	A
44	3,013	3,012	1	0	0	*x*	*x*	*x*	*y*	*y*	18	3.3	A
45			1	11	0								
46	900	700	0	0	0	*x*	*x*	*x*	*y*	*y*	42	*y*	P
47	1,600	1,500				*x*	*y*	*y*					
48	3,200	3,000				1,450	*y*	*y*					
49	4,400	4,000	1	2	0						19	3.0	A
50			1	2	0								
51	3,000	2,050				1,175	exhausted						
52	1,200	800	0	305	0	*x*	*x*	*x*	*y*	*y*	44	0.14	P
53	4,000	3,600	0	11	0	*x*	*x*	*x*	*x*	*x*	23	2.6	A
54			0	316	0								
55	1,050	1,000	0	8	0	*x*	*x*	*x*	*y*	*y*	48	0	P
56	2,600	2,300	0	29	0	*x*	*x*	*x*	26	18	23	2.3	A
57	2,860	2,700	0	1	0	*y*	*y*	*y*	*x*	*x*	21	3.0	A
58			0	30	0								
59	1,600	1,200	0	2	0	490	exhausted					43	P
60	1,000	650	*y*	*y*	*y*	*x*	*y*	*y*	45	19	28	0.18	M
61	3,760	3,730	0	1	0	*x*	*x*	*x*	*x*	*x*	26	3.2	A
62	3,200	2,900	0	5	0	1,175	*y*	*y*	*y*	*y*	42	0.14	P
63	3,700	3,650	0	2	0	*x*	*x*	*x*	*y*	*y*	41	0.14	P
64			0	7	0								
65	1,500	1,300	0	2	0	*x*	*x*	*x*	*y*	*y*	21	2.6	A
66	1,800	1,700	0	5	0	*x*	*x*	*x*	*y*	*y*	23	2.9	A
67			0	7	0								
68	1,500	1,200				445	*y*	*y*					
69	2,700	2,650				850	*y*	*y*					
70	4,100	3,900				1,425	*y*	*y*					

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1934			Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1934				
			Number of Wells				Average at End of		Gravity A.P.I. at 60° F.				
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Initial	1933	1934	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
71	600	300	0	29	0	*x*	*x*	*x*	*y*	*y*	30	*y*	M
72	1,600	1,500	0	25	0	*x*	*x*	*x*	*y*	*y*	32	0.2	M
73	1,700	1,600	0	2	3	*x*	*x*	*x*	*y*	*y*	32	*y*	M
74	2,000	1,900	1	0		*x*	*x*	*x*	*y*	*y*	35	*y*	M
75	4,000	3,900	1	56	3	*x*							
76						825	*y*	*y*					
77	2,300	2,200				1,170	*y*	*y*					
78	2,700	2,600	1	0	0	*y*	*y*	*y*	*x*	*x*	34	1.3	M
79			1	0	0								
80	1,700	1,450	0	0	0	*x*	*x*	*x*	*x*	*x*	22	2.9	A
81	5,250	5,200	0	1	0	*x*	*x*	*x*	*y*	*y*	32	0.3	M
82													
83	1,550	1,500	0	18	0	*x*	*x*	*x*	*x*	*x*	32	0.17	M
84	3,180	3,170	0	1	0	*x*	*x*	*x*	*x*	*x*	26	2.4	A
85			0	19	0								
86	4,400	4,350				1,450	*y*	*x*					
87	2,575	2,550				825	*y*	*y*					
88	3,000	2,950				1,335	*y*	*y*					
89	3,400	3,350				1,485	*y*	*y*					
90													
91	2,400	2,200				400	*y*	*y*					
92	3,210	3,200	0	0	0	*x*	*x*	*x*	*x*	*x*	23	*y*	A
93	3,700	3,475	0	1	0	*y*	*x*	*x*	*x*	*x*	16	3.9	A
94	2,850	2,800	0	3	0	*x*	*x*	*x*	*x*	*x*	23	1.7	A
95	1,550	1,500				700	*y*	*y*					
96	3,900	3,500	0	15	0	*x*	*x*	*x*	*y*	*y*	21	3.3	A
97			0	15	0								
98	1,525	1,500	0	390	0	*x*	*x*	*x*	*y*	*y*	41	0.10	P
99	1,000	800	0	11	0	*x*	*x*	*x*	*y*	*y*	36	0.1	M
100	3,370	3,350				800	*x*	*x*					
101			0	11	0								
102	1,840	1,830				700	*x*	*x*					
103	3,900	3,750	0	1	0	*y*	*x*	*x*	*x*	*x*	18	0.35	A
104	500	250	0	0	0	*x*	*x*	*x*	*x*	*x*	42	0.19	P
105	1,425	1,400	0	15	0	525	*x*	*x*	*y*	*y*	22	2.8	A
106	1,350	1,315				530	*y*	*y*					
107	3,175	3,145	0	1	0	*y*		*y*	*y*	*y*	35	*y*	M
108	3,900	3,800	0	4	0	*x*	*x*	*x*	*y*	*y*	34	0.37	M
109	2,800	2,600	0	48	0	*x*	*x*	*x*	*y*	*y*	35	0.26	M
110	1,100	1,000	0	384	0	*x*	*y*	*y*	*y*	*y*	36	0.15	M
111	1,575	1,500	0	1,565	0	*x*	*y*	*y*	*y*	*y*	36	0.16	M
112	2,350	2,300	0	78	0	*x*	*y*	*y*	*y*	*y*	35	0.4	M
113	2,875	2,750	20	25	0	*x*	*y*	*y*	*y*	*y*	35	1.3	M
114	3,980	3,790	1	0	0	*x*	*y*	*y*	*x*	*x*	28	2.3	A
115			21	2,052	0								
116	900	800	0	0	0	*x*	*x*	*x*	*x*	*x*	24	*y*	A
117	675	625	0	0	0	*x*	*x*	*x*	*x*	*x*	21	0.17	A
118	2,700	2,600	0	1	0	*x*	*x*	*x*	*y*	*y*	15	4.5	A
119	2,514	2,475	0	1	0	*y*	*y*	*y*	*x*	*x*	18	*y*	A
120	1,125	1,100	0	3	0	*y*	*x*	*y*	*x*	*x*	22	3.24	A
121	4,250	3,900	0	1	0	*y*	*x*	*y*	*x*	*x*	16	*y*	A
122	900	400	0	11	0	*x*	*x*	*x*	*y*	*y*	38	*y*	M
123	2,950	2,900	0	0	0	*x*	*x*	*x*	*x*	*x*	35	0.15	M
124	1,600	1,200	0	2	0	*x*	*x*	*x*	*y*	*y*	35	*y*	M
125			0	2	0								
126	600	400	0	0	0	*x*	*x*	*x*	*x*	*x*	46	*y*	P
127	800	700	0	0	0	*x*	*x*	*x*	*x*	*x*	21	*y*	A
128	3,807	3,775	0	1	0	*y*		*y*	*x*	*x*	28	1.8	
129													
130	2,260	2,210				850	*y*	*y*					
131	3,550	3,500				1,800	*y*	*y*					
132	3,750	3,700				1,350	*y*	*y*					
133													
134	4,120	4,100				1,520	*y*	*y*					
135													
136			27	3,413	3								

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1934		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
1	*y*	*y*	Morrison	Jur	S	Por	30	A	18	Chugwater	5,460
2	*y*	*y*	Sundance	Jur	S	Por	40	A	3	Chugwater	4,083
3			Dakota	CreU	S	Por	6	A	2	Lakota	4,257
4			Frontier	CreU	S	Por	40	A	0	Frontier	8,725
5	*y*	*y*	Frontier	CreU	S	Por	16	AF			
6	1,040	*y*	Dakota	CreU	S	Por	50	AF			
7									5	Nugget	3,822
8			Shannon	CreU	S	Por	65	A			
9			Wall Creek	CreU	S	Por	100	A			
10			Dakota	CreU	S	Por	15	A			
11									225	Sundance	4,763
12	1,020	*y*	Wall Creek	CreU	S	Por	150	A			
13	*x*	*x*	Morrison	Jur	S	Por	22	A			
14									3	Sundance	5,345
15	890	*y*	Frontier	CreU	SH	Por	20	A	5	Muddy sand	4,400
16			Embar	Per	L	Cav	35	A			
17			Tensleep	Pen	S	Por	100	A			
18									2	Madison	3,832
19			Sundance	Jur	S	Por	10	Af			
20			Embar	Per	L	Cav	15	Af			
21									11	Amsden	2,867
22	*y*	*y*	Shannon	CreU	SH	Por	70	A	1	Niobrara Shale	5,200
23	*y*	*y*	Frontier	CreU	S	Por	30	AF			
24			Sundance	Jur	S	Por	10	AF			
25			Tensleep	Pen	S	Por	70	AF			
26									3	Amsden	5,505
27			Tensleep	Pen	S	Por	50	A	0	Tensleep	650
28			Embar-Tensleep	Per-Pen	L-S	Cav-Por	150	A	23	Tensleep	1,400
29											
30			Shannon	CreU	SH	Por	40	A			
31			Muddy	CreU	S	Por	30	A			
32									1	Lakota	5,075
33	*y*	*y*	Dakota	CreU	S	Por	30	A			
34	*y*	*y*	Sundance	Jur	S	Por	110	A			
35	*y*	*y*							5	Sundance	3,100
36	*y*	*y*	Dakota	CreU	S	Por	50	A	4	Chugwater	4,560
37			Frontier	CreU	S	Por	40	AF			
38	*y*	*y*	Dakota	CreU	S	Por	55	AF			
39									39	Dakota	2,450
40	*x*	*x*	Frontier	CreU	S	Por	40	A	0	Dakota	3,992
41	*y*	*y*	Mowry-Dakota	CreU	S	Por	25	A	8	Tensleep	4,600
42			Tensleep	Pen	S	Por	60	A	1	Tensleep	3,350
43			Tensleep	Pen	S	Por	100	AF			
44			Madison	Mis	L	Cav	*x*	AF			
45									4	Madison	3,013
46			Frontier	CreU	S	Por	35	AF			
47	*y*	*y*	Dakota	CreU	S	Por	50	AF			
48	*y*	*y*	Embar-Tensleep	Per-Pen	L-S	Por-Cav	100	AF			
49	*x*	*x*	Madison	Mis	L	Cav	200?	AF			
50									83	Madison	4,424
51	*x*	*x*	Mesaverde	CreU	S	Por	50	A	5	Cody	4,019
52			Frontier	CreU	S	Por	200	A			
53			Embar-Tensleep	Per-Pen	L-S	Cav-Por	200	A			
54									85	Amsden	4,336
55			Greybull	CreU	S	Por	20	MC	115	Tensleep	2,950
56			Embar	Per	L	Cav	50	Af			
57			Tensleep	Pen	S	Por	60	Af			
58									2	Tensleep	2,886
59	*x*	*x*	Frontier	CreU	S	Por	120	A	8	Morrison	2,785
60			Wasatch	Eoc	S	Por	150	A	53	Hilliard	4,210
61			Embar	Per	L	Cav	30	A	2	Tensleep	3,830
62	*y*	*y*	Dakota	CreU	S	Por	70	A			
63			Sundance	Jur	S	Por	15	A			
64									54	Sundance	3,731
65			Embar	Per	L	Cav	60	A			
66			Tensleep	Pen	S	Por	125	A			
67									8	Tensleep	2,190
68	1,000		Frontier	CreU	S	Por	100	A	4	Mowry	1,670
69	*y*	*y*	Frontier	CreU	S	Por	50	A	0	Frontier	2,915

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1934		Producing Rock						Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	B.t.u. per Cu.Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]		Name	Depth of Hole, Ft.
70	*y*	*y*	Frontier	CreU	S	Por	15	A	0	Frontier	4,420
71			Frontier	CreU	S	Por	100	Af			
72			Dakota-Lakota	CreU, L	S	Por	80	Af			
73			Sundance	Jur	S	Por	200	Af			
74			Tensleep	Pen	S	Por	65	Af			
75									37	Tensleep	4,009
76	*y*	*y*	Dakota	CreU	S	Por	30	A			
77	*y*	*y*	Sundance	Jur	S	Por	110	A			
78			Tensleep	Pen	S	Por	150	A			
79									6	Tensleep	4,690
80			Embar	Per	L	Cav	50	A	3	Tensleep	2,094
81			Wall Creek	CreU	S	Por	30	A	4	Chugwater	6,689
82											
83			Lakota	CreL	S	Por	25	A			
84			Minnelusa	Pen	S	Por	15	A			
85									11	Minnelusa	3,185
86	*x*	*x*	Frontier	CreU	S	Por	35	AF	1	Chugwater	6,081
87	*y*	*y*	Frontier	CreU	S	Por	40	AF			
88	*y*	*y*	Dakota	CreU	S	Por	20	AF			
89	*y*	*y*	Sundance	Jur	S	Por	15	AF			
90									5	Sundance	3,800
91	*y*	*y*	Frontier	CreU	S	Por	30	AF	1	Frontier	2,800
92			Tensleep	Pen	S	Por	5	A	2	Tensleep	3,308
93			Tensleep	Pen	S	Por	60	A	1	Tensleep	3,712
94			Tensleep	Pen	S	Por	40	A	4	Tensleep	2,830
95	*y*	*y*	Dakota	CreU	S	Por	35	A			
96			Embar-Tensleep	Per-Pen	L-S	Cav-Por	150	A			
97									7	Madison	4,160
98			Newcastle	CreU	S	Por	10	ML	456	Minnelusa	2,150
99			Niobrara	CreU	H	Fis	*x*	A			
100	*x*	*x*	Muddy	CreU	S	Por	18	A			
101									45	Sundance	4,630
102	*y*	*y*	Tensleep	Pen	S	Por	25	A	13	Deadwood	3,127
103			Tensleep	Pen	S	Por	40	A	0	Tensleep	3,903
104			Mowry	CreU	H	Fis	*x*	A	18	Embar	2,500
105	*x*	*x*	Sundance	Jur	S	Por	35	A	5	Tensleep	2,645
106	*y*	*y*	Frontier	CreU	S	Por	35	A	10	Chugwater	3,460
107			Muddy	CreU	S	Por	20	A	2	Muddy	3,175
108			Dakota	CreU	S	Por	50	A	1	Lakota	3,930
109			Dakota	CreU	S	Por	110	A	11	Chugwater	3,390
110			1st Wall Creek	CreU	S	Por	110	Af			
111			2nd Wall Creek	CreU	S	Por	65	Af			
112			Lakota	CreL	S	Por	20	Af			
113			Sundance	Jur	S	Por	70	Af			
114			Tensleep	Pen	S	Por	190	Af			
115									229	Granite	5,400
116			Shannon	CreU	S	Por	75	MuP	41		
117			Quealey	CreU	SH	Por	40	A	16	Steele	6,931
118			Tensleep	Pen	S	Por	150	A	5	Tensleep	2,500
119			Embar	Per	L	Cav	40	A	0	Embar	2,514
120			Sundance	Jur	S	Por	25	A	8	Tensleep	2,705
121			Tensleep	Pen	S	Por	150	A	0	Amsden	4,255
122			Aspen	CreU	H	Fis	*x*	MC	65	Bear River	2,065
123	*y*	*y*	Wall Creek	CreU	S	Por	40	Af			
124			Steele	CreU	H	Fis	*x*	Af			
125									10	Frontier	3,140
126			Mowry	CreU	S	Por	50	A	95	Madison	4,165
127			Embar	Per	L	Cav	65	A	18	Tensleep	1,590
128			Embar	Per	L	Cav	35	A	4	Embar	3,807
129											
130	*y*	*y*	Frontier	CreU	S	Por	50	A			
131	*y*	*y*	Dakota	CreU	S	Por	50	A			
132	*y*	*y*	Lakota	CreL	S	Por	40	A			
133											
134	*y*	*y*	Sundance	Jur	S	Por	20	A	4	Sundance	4,150
135											
136											

TABLE 2.—*Summary of Drilling Operations in Wyoming*
(Figures in body of tabulation represent number of holes.)

County	Completed Prior to January 1, 1935											Completed during 1934							Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes										Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes						Productive Wells (For Details, See Table 1)		
	Total Depths, Ft.									Total		Total Depths, Ft.					Total			
	Less than 1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000	8000–9000			Less than 1000	1000–2000	2000–3000	3000–4000	4000–5000			Within Fields	Exploratory
Albany	5	14	6	7	1	0	0	0	0	33	5	0	0	0	1	0	1	1	0	0
Big Horn	212	119	16	3	2	0	0	0	0	352	37	3	2	0	0	1	6	1	5	3
Campbell	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Carbon	44	24	38	35	14	1	2	0	0	148	118	0	1	0	0	1	2	2	0	5
Converse	18	105	28	102	1	0	0	0	0	254	173	5	1	0	0	0	6	0	0	2
Crook	8	2	3	0	0	0	0	0	0	13	0	2	0	2	0	0	4	0	0	0
Fremont	85	54	29	13	2	0	0	0	0	183	148	0	1	0	1	0	2	1	0	2
Goshen	2	2	0	0	0	2	0	0	0	6	0	1	0	0	0	0	1	0	0	0
Hot Springs	75	66	16	9	2	0	0	0	0	168	408	0	0	0	0	1	1	2	0	0
Johnson	8	6	7	4	1	0	0	0	0	26	8	0	0	0	0	0	0	0	0	0
Laramie	5	0	0	1	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
Lincoln	23	16	8	1	1	0	0	0	0	49	42	1	1	0	0	0	2	1	1	0
Natrona	59	81	246	22	6	1	2	0	0	417	2191	0	2	0	0	0	2	1	0	0
Niobrara	15	14	26	45	2	0	0	0	0	102	55	0	2	0	0	0	2	0	0	1
Park	20	38	12	10	4	0	0	0	0	84	214	0	1	0	0	0	1	8	0	2
Platte	2	2	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Sheridan	1	0	1	0	0	0	0	0	0	2	0	0	0	1	0	0	1	0	0	0
Sublette	28	32	6	1	1	1	0	0	0	69	60	2	0	1	0	0	3	0	1	
Sweetwater	7	13	27	7	2	0	0	0	0	56	86	0	0	0	1	0	1	2	1	0
Uinta	38	35	5	3	2	1	0	0	0	84	29	2	2	0	1	0	5	0	0	1
Washakie	15	11	4	1	1	0	0	0	1	33	13	0	2	0	0	0	2	2	2	0
Weston	213	203	57	6	1	1	0	0	0	478	399	8	1	3	0	0	12	13	3	1
Total	883	838	535	270	43	7	4	0	1	2574	3986	24	16	7	4	3	54	34	13	17

reserves to last many years, and until markets are expanded there is little need for more wells. A small new pool of gas was discovered in the Wall Creek sands around 1200 ft., in a fault block on the south end of the large Oregon Basin anticline. Only one well has been drilled, so its importance is unknown, but it cannot cover a large area.

The figures for gas production for 1934 are estimates because the correct figures are not compiled and available at the time of writing. Most of the 1933 and total figures for gas production are given as estimates because the correct figures are not available to the author for publication, and the same is true of reservoir pressures.

In the Rocky Mountain states there are few accurate figures on reservoir pressures of oil fields. In the years when these fields were drilled, few paid attention to surface pressure figures, no bottom-hole pressures were taken, and there are only rough estimates of what the original pressure might have been. Now, since most pressures are low, many operators have not considered accurate pressures necessary, but more determinations are being made and more data are being accumulated. As comparisons are made and work done, pressure data should become available in the future.

Petroleum Development in Arabia for the Year 1934

By G. C. Gester* Member A.I.M.E.

(New York Meeting, February, 1935)

With the exception of exploration geological work that is being prosecuted in various parts of the mainland of Arabia, the only new developments in Arabia during 1934 were on Bahrein Island, which is in the southwestern portion of the Persian Gulf, approximately 25 miles from the mainland of Arabia. Here the Standard Oil Co. of California, through its wholly owned subsidiary, The Bahrein Petroleum Co., Limited, has continued to carry on a systematic drilling campaign and has constructed camps, pipe line and marine loading facilities.

During 1934 eight wells have been completed at depths ranging from 2058 to 2253 ft. These wells have shown average initial productions ranging from 1500 to 5000 bbl., with one, No. 15, estimated as being capable of flowing as much as 11,000 bbl. per day. The oil is asphaltic in character and has a gravity range of from 32° to 34° A.P.I.

The locating of all new wells has followed a plan of orderly development, with the ultimate object of obtaining efficiency of operation and maximum production. The wells are taking a penetration of 200 to 250 ft. of the lower or so-called Main productive zone. The upper oil zone, which is cased off, includes 300 to 400 ft. of alternating limestones, clays and shales and carries a heavier oil under lower pressures. The Main zone is similar lithologically to the upper zone. Micro-fauna collected from cores have shown that the oil occurs in formations of lower Eocene and Cretaceous age. Development to date has not progressed sufficiently so that either the maximum thickness of the oil-bearing horizons or the limits of the field can be determined. Something over 10,000 acres has been proven to date.

Among other developments leading toward the marketing of oil from Bahrein during 1934 was the construction of a marine loading terminal. This included the laying of over 3 miles of 12-in. submarine pipe line from the small island of Sitra out into the harbor, terminating in 50 ft. of water; also the laying of more than 10 miles of gathering lines from the producing area to the terminal. Three crude oil working tanks with floating roofs were erected on Sitra Island, having a capacity of 250,000 bbl. A pumping plant was provided having a capacity of 5700 bbl. of oil per hour. This is housed in a dustproof building, as rather severe

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* Standard Oil Company of California, San Francisco, Calif.

sand storms, locally called "shamals," are not infrequent on Bahrein during certain seasons.

The road to the terminal required the construction of a fill or trestle 1200 ft. long and a drawbridge across the channel between the island of Bahrein and the island of Sitra.

These loading facilities will make it possible to handle 10,000 bbl. of oil per day, and there are provisions for adding booster pumps to double that capacity if greater production is desired.

Oil Production in Australia

By W. G. Woolnough*

(New York Meeting, February, 1935)

Production of oil in Australia is negligible at present. A very small quantity of crude is being recovered from lean pumpers in Victoria, and a little activity is evidenced in Queensland, where two new wells were sunk during 1934. One of these, at Warooby Creek near Roma, obtained a noteworthy gas flow, but no oil production has been recorded. Geological investigation is going on in Western Australia, but no drilling activity is apparent. The "boom" in oil prospecting came to an end when the wave of depression swept over the country, and the investing public turned its attention actively towards gold. There is great activity in gold prospecting at present.

I still maintain as strongly as ever that the prospects of obtaining flow oil in Queensland, Western Australia and Victoria are good, and that really scientific methods must ultimately succeed.

Active and excellent geological work is being carried out in the Mandated Territory of New Guinea, and it is reported that drilling is likely to be undertaken next year. Matters in Papua are at a standstill.

The question of extraction of oil from the oil shales of New South Wales and Tasmania is perennially active, and attempts to exploit this source commercially are renewed from time to time. Hydrogenation of coal is also receiving a good deal of attention.

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* Canberra, F.C.T., Australia.

Oil and Gas Development in the Argentine Republic during 1934

By G. Hileman*

During the year 1934 there were no new or extraordinary developments in the proven fields. With few exceptions all companies operating in these fields continued intensive exploitation programs on their old properties in an attempt to maintain the normal production of former years. In one or two instances these exploitation activities have had such marked success that the total production for 1934 slightly surpassed that of 1933. The most striking increase in production is that shown by the Kilometer 27 pool of the Comodoro Rivadavia field. However, this increase cannot be attributed to intensive drilling, since it is the result of a more uniform daily withdrawal distributed among all the productive wells. The Province of Salta also showed another increase, so that, judging from the statistics of the past three years and in view of proposed exploration projects, the future may reveal some interesting developments in this province.

One of the most interesting occurrences in Salta is the discovery, though not yet considered commercial, made at Macueta, near the boundary line between the Argentine and Bolivia. This exploration well was drilled by the Standard Oil Co. of New Jersey and is the northernmost exploratory well in the republic. The oil from this well is of the same type and commercial value as that produced in the San Pedro and Lomitas fields. The producing horizon is also the same as that in the other Salta fields; that is, the Paleozoic Permo-Carboniferous.

Table 1.—*Oil and Gas Production in the Argentine Republic*

Line Number	Field, *Area*	Age, Years to End of 1934	Area Proved, Acres	
			Oil and Gas[a]	Total
1	Comodoro Rivadavia, *Territory of Chubut*	27	19,768	19,768
2	Plaza Huincul, *Territory of Neuquen*	16	2,964	2,964
3	Salta, *Province of Salta*	9	5,000	5,000
4	Cacheuta, *Province of Mendoza*	3		
5	Tupungato, *Province of Mendoza*	1		
6	Rio Atuel, *Province of Mendoza*	9		

[a] Footnotes to column heads and explanation of symbols are on page 249.

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* Bureau of Mines, Buenos Aires, Argentine Republic.

Mention should also be made of the exploration drilling being done by the Astra in the southern part of the province. Numerous exploration permits have been solicited in this region and the next year should witness the initiation of additional exploration drilling.

Practically all of the work in other parts of the republic under exploration was done by the Government entity, Yacimientos Petroliferos Fiscales, to which three discoveries may be credited. The economic importance of each is yet to be determined.

The first positive discovery is in the Province of Mendoza, Department of Tupungato, south of the Cacheuta field, which was first drilled and exploited on a small scale a number of years ago. The Tupungato well has an average production of about 25 bbl. per day from a depth of 249 m. Encouraged by this discovery, the Y.P.F. has initiated an active geological, geophysical and drilling campaign in this part of the province. The producing horizon is Tertiary.

The second discovery may be considered as highly important since it has some gas production under moderate pressure from the Cretaceous at 445 m. This well is in the northeastern part of the Territory of Santa Cruz near the town of Las Heras, the terminus of the railway from Puerto Deseado on the Atlantic coast.

The region also lies about 120 km. to the southwest of the Comodoro Rivadavia field, which it resembles in some respects. However, it has a distinct advantage in that the structural conditions are indicated by the surface geology, thereby dispensing with geophysical work for locating structure.

The third showing, or discovery, was made by Yacimientos Petroliferos Fiscales about the end of the year in the Province of Jujuy. The drilling of this exploration well represents a renewal of drilling operations abandoned in the same region approximately 10 years ago. Gas and oil production are reported at a depth of 1590 m. The well is approximately 30 km. and east of Yuto, a station on the State railways, in a place called Saladillo de la Brea.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production Bbl.			Total Gas Production, M. Cu. Ft.			
	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933	During 1934	Maximum Daily during 1934
1	106,383,878	10,307,992	10,853,301	33,622	5,382	215	16	135,600	19,011	21,184	6.3
2	10,149,201	1,432,640	1,085,740	2,833	3,423	54	10	10,178	2,348	2,183	6.7
3	6,207,338	1,909,245	2,034,768	6,356	1,241	177	52	4,207	1,747	2,461	7.4
4	24,319	8,566	14,167	39							
5	1,888		1,888	10							
6	183,028	45,770	37,096	100							

All other exploration work cited for the previous year in the provinces of Mendoza, Sante Fe and Tucuman is still in progress. As this is written no shows have been encountered important enough to indicate possibilities at greater depths.

The wells reported drilling in the Territory of Rio Negro near Bariloche during 1933 and 1934 resulted negatively and work there has ceased.

In view of the encouragement derived from the exploration campaign in Salta during recent years, it may be said that the extensive though not intensive exploration program now in progress from the extreme north to the southern territories of the republic indicates the fervent interest of the Argentine Government in the oil industry. This is especially true because fuel constitutes one of the primary essentials for the industrial development of the country. In support of this statement, mention of the geological work to be initiated in the Province of San Juan during 1935 by the Yacimientos Petroliferos Fiscales should be made.

In résumé, after making a careful review of the production statistics of the existing fields, the following conclusions may be drawn:

1. The maintenance of a more or less constant production in Comodoro Rivadavia was due: (*a*) to the drilling of new wells to offset the natural production decline, (*b*) to intensive exploration and (*c*) to the notable increase in production from the field at Kilometer 27 operated by private capital.

2. There was an increase in production in Salta due to the intensive development of the San Pedro field owned by private enterprise.

3. A noticeable decrease in production from the Plaza Huincul field in Neuquen, in spite of an aggressive drilling program both in exploitation and exploration. All exploration wells were unsuccessful, nevertheless the region is still interesting and will require extensive expenditures to test it properly.

TABLE 1.—(*Continued*)

	Number of Oil and/or Gas Wells								Average Depth, Ft.		Oil Production Methods At End of 1934					Pressure, Lb. per Sq. In.^{e}		
		During 1934		At End of 1934							Number of Wells						Average at End of	
Line Number	Completed to End of 1934	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas^c	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Miscellaneous	Initial	1933	1934
1	2,885	211	56	537		1,887	47	1,934	1,850	1,810	10	1,729	110	3	35	1,102	40	40
2	372	31	5	41		280	14	294	2,501	2,411	10	260	6		2	910	25	25
3	205	41	16	48		120		120	1,850*y*	1,840*y*	5	115				*y*	30	25
4	8	5	2		6			6	1,810	1,806					6			
5	3	3			3			3	960	955					3			
6	7	2			7			7	650	643					7			

4. The increase of production in the Province of Mendoza was due to the exploitation of the Cacheuta wells and the three new producers at Tupungato and El Sosneado.

During the 1934 sessions of the Federal Congress, the new oil law was fully considered and discussed. After approval by the Senate in September, 1932, it passed to the Chamber of Deputies, where it was approved in a modified form in September, 1934. The modified bill then passed to the Senate for reconsideration, where all House modifications except two were accepted and approved. The consideration of these two articles is pending business for the next meeting of the Chamber of Deputies.

This means that 34 of the 36 articles contained in the bill, and incorporated as a part of the Mining Code, have been definitely approved and the final sanction of the bill seems almost an accomplished fact. In spite of the fact that the law may be considered as basically nationalistic, the provisions for exploration concessions and the periods established for the exploration work are liberal.

Out of each exploration permit of 2000 hectares, which may remain in exploration for more than 3½ years, the state will grant mining rights or titles to 1000 hectares if a discovery is made within the period prescribed by law. The remainder reverts to the Government as an automatic reserve which may be exploited by the Government entity or by mixed companies composed of Government and private capital.

The concessionaire must pay the Government an annual rental of one paper peso per hectare on exploration acreage, and 10 paper pesos per hectare for mining titles or pertenencia obtained after discovery is made. The royalty to be paid to the province or Federal Government

TABLE 1.—(*Continued*)

	Character of Oil, Approx. Average during 1934					Character of Gas Approx. Average during 1934		Producing Rock							Deepest Zone Tested to End of 1934	
	Gravity, A.P.I. at 60° F.															
Line Number	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1934	Name	Depth of Hole, Ft.
1	32	17	21	0.18	P A	849	0.10 0.52	Chubutiano and Clauconitico	Cre	Ss	Por	25*y*	AF MU	233	Lower Chubutiano Possibly Lower Cre	6,617
2	40	30	34	0.30	M	877	1.50	Dogger	Jur M	S	Por	63*y*	Af	37	Liassic	4,826
3	50	44	47	0.10	P		1.50	Clay-grit series	Per-Car	Ss	Por	7*y*	A	15	Devonian	4,300
4			18	0.18	P			Red Beds	CreU	Ss	Por	4*y*	Af	2	Tri U	3,048
5			20	0.11	P			Calchaqueño	Ter	Ss	Por	5*y*	AF	0		
6			12	1.00	A			Ranchhouse Conglomerate	Ter	Ss	Por	4*y*	MIF	4		

varies from 8 to 12 per cent, with the Federal Government exercising the control, thereby permitting an adjustment to varying conditions. Under this law, with careful regulation, in the near future, the country should increase exploration and exploitation activities. Also, considering the results already obtained in widely separated parts of the country, the Argentine may be able to produce enough crude to supply its consumption.

In conclusion, it should be noted that the accompanying statistics are not differentiated for individual pools but cover the total production of a territory or province except in the case of Mendoza. However, it is hoped that next year, owing to a revised plan for assembling data, using the various pools as units, it will be possible to submit a report conforming more closely to the standards desired for this publication.

Attention is called to the fact that in the 1933 report [*Trans.* A.I.M.E. (1934) **107**, 355] an error crept into the figures given for proven acreage in Chubut and Neuquen. However, the per acre recovery was calculated on the true proven acreage figures.

Further, in Table 1, in the column headed "Completed to End 1933," the number of wells given in the 1933 report included all wells irrespective of their results. This year dry holes have been deducted, so that the cipher represents the total number of productive wells only.

Certain new information with regard to dry holes and other features has necessitated adjustments in the tables, which introduce discrepancies with 1933 figures. The accompanying tabulation can be considered as representing the most authoritative information to date.

TABLE 2.—*Summary of Drilling Operations in the Argentine Republic*

(Figures in body of tabulation represent number of holes.)

Area	Completed Prior to Jan. 1, 1935									Completed during 1934						Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes								Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes					Productive Wells (For Details, See Table 1)		
	Total Depths, Ft.									Total, Depths, Ft.							
	500–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	Total[1]		1000–2000	2000–3000	3000–4000	4000–5000	Total		Within Fields	Exploratory
Territory of Chubut		8	280	12	1	1	1	303	2,885		3	18	2	23	211	30	6
Territory of Neuquen		6	25	41	5			77	372			5	1	6	31	7	5
Territory of Rio Negro	3	1		1				5	0	1		1		2	0	0	0
Territory of Santa Cruz		1	4	2	2	1		10	0								1
Province of Jujuy			5	2	1			8	0					0	0		1
Province of Salta		2	16	13	2			33	205		5	1		6	35	13	11
Province of Santa Fe																	1
Province of Mendoza		3	3	1				7	18		2			2	8	2	5
Province of Tucumán																	1
Province of Santiago del Estero																	1

[1] Total number of dry and/or near-dry holes within or without fields.

Petroleum in Austria, Hungary and Czechoslovakia in 1934

By Walter M. Small,* Member A.I.M.E.

(New York Meeting, February, 1935)

Austria.—Austria produced some 430 cisterns of 10,000 kg. each of crude oil of a 0.9428 sp. gr. during 1934. Gösting II well near Zistersdorf was placed on the pump in August and at the end of the year was still producing about three cisterns daily. This well is owned by the Erdöl-Produktionsgesellschaft while Gösting I is owned by Raky-Danubia. Only five wells were completed in the republic during the year. These accounted for 1783.5 meters of the 2225 meters drilled. The only producer completed was Gösting II. At the close of the year, four rigs were in operation and one rigging up. At least 8 or 10 new wells are planned in Lower Austria for 1935. The European Gas & Electric Co. put its 6-km. gas line into operation in May and has sold 12,301,550 cu. m. of gas to the Vienna City Electric Works. A 2-km. pipe line was built from Gösting II to the railway loading rack near Zistersdorf.

Hungary.—No oil or gas was produced except a small amount of gas trapped from flowing artesian wells. The Government completed and abandoned a 1500-m. hole at Tisztaberek in northeastern Hungary and is drilling at 967 m. near Bogács, 120 km. northeast of Budapest. It is unofficially reported it plans to drill two new wells in 1935. The European Gas & Electric Co. has a rig up for a test at Mihalyi in Transdanubia.

Czechoslovakia.—In Gbely (Egbell) there were produced 1283 cisterns of 10,000 kg. of 0.935 sp. gr. oil and a small amount of gas used for fuel. This field is operated by the Government; 17 shallow producing wells and three dry holes were drilled, with a total of 3351 m. of hole completed.

In Hodonin (Göding) there were produced approximately 1300 cisterns of 10,000 kg. each of 0.91 sp. gr. oil and a small amount of gas used for fuel. The field is operated by the Apollo, which drilled four producing wells averaging 460 m. in depth, one small gas well of 550 m., one small gas well 260, and one dry hole 230 m. Two wells were deepened a total of 80 meters.

The Government is drilling below 800 m. in a wildcat test in eastern Czechoslovakia near the Rumanian frontier.

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Petroleum Development and Production in Bolivia

By Jorge Muñoz Reyes*

(New York Meeting, February, 1935)

There are three main oil areas in Bolivia (Fig. 1) although so far only one has yielded petroleum in commercial quantities. The Sub-Andean zone is along the easternmost ranges of the Andes, bordering the large eastern and northeastern lowlands. It extends from the Peruvian frontier, north of Lake Titicaca in a southeasterly direction towards the city of Santa Cruz and from there southward to the Argentine border. This zone forms a belt about 1200 km. long by 100 km. wide, and comprises a series of parallel, very rugged, low ranges. Oil has been known and utilized by the natives in these regions since colonial times, from the large number of seepages, which in modern times have led to the discovery of many fields.

The second oil zone of Bolivia lies along the eastern and southern borders of Lake Titicaca, on the Andean high plateau, at an average altitude of 13,000 ft. above sea level. It comprises an area of approximately one million hectares (2,470,000 acres). Several seepages are known here, but little development has taken place, because of the difficulties encountered, as the greater part of the territory is covered by volcanic tuffs and ashes, which conceal the structure underneath.

The third area is called the "Central zone," and is in the heart of the country, in the Department of Cochabamba, covering approximately five million hectares (12,350,000 acres). This area consists mainly of broad valleys flanked by low rolling ranges. Natural seepages are not known to exist, but there are secondary evidences of the presence of oil. The outcropping rocks are mainly Paleozoic (Silurian and Devonian sandstones and shales). Albertite and other forms of polymerized petroleum have been found in this region.

Of these three main oil areas, only the first one is at present productive on a small commercial scale. This zone, developed almost exclusively by the Standard Oil Co. of Bolivia, a subsidiary of the Standard Oil Co. of New Jersey, is divided from south to north into the following local fields:

1. Bermejo (On the Argentine border)
2. San Telmo
3. Sanandita
4. Caigua
5. Camatindi
6. Machareti

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* Direccion General de Minas y Petroleo, La Paz, Bolivia.

7. Buena Vista
8. Camiri
9. Saipurú
10. Guariri
11. Tatarenda
12. Espejos
13. Isiboro
14. Chapare
15. Caupolicán

The first 11 fields are controlled almost entirely by the company mentioned. Espejos field is controlled by a Bolivian firm called Compañía Petrolífera Velasco, while the other three fields are in the stage of early development and are not yet productive.

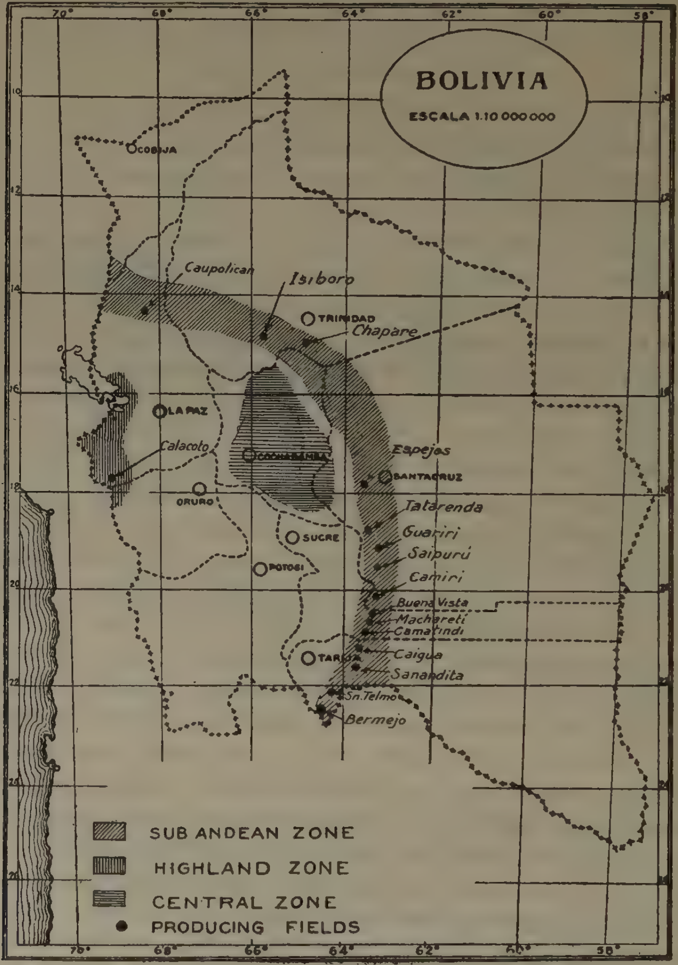

FIG. 1.—PRINCIPAL OIL AREAS IN BOLIVIA.

PRODUCTION

Commercial production has been restricted enormously by the lack of good roads and of proper means of transportation.

On account of the state of war in which Bolivia has been involved since June, 1932, and owing to the invasion of Paraguay on Bolivian territory, the solution of the problem of transportation and export of petroleum and its products has been greatly retarded. At present, only two fields are in production to supply local consumption; namely, the Sanandita and Camiri. In each of these fields there is a small distilling plant or refinery. These two topping plants were not built with the intention of rendering a commercial production but merely to provide the Standard Oil Co., which was developing and wildcatting the territory, with cheap fuel for its motorized vehicles and other needs on their properties. Later on, in 1931, that company started to sell the surplus production in the small towns of the vicinity. Finally, the country having become involved in the war being waged near that oil

TABLE 1.—*Chart of Drilling Operations by the Standard Oil Company of Bolivia*

District	No. of Well	Lot or Concession	Elevation Above Sea Level, Meters	Depth, Meters	Initial Production in 24 Hr., Bbl.	Productive Horizons	
						Oil	Gas
Bermejo	1	Lot No. 1	572.0	560.8	Abandoned	2	1
	2		432.0	635.5	1,200	12	4
	3		538.0	213.4	Abandoned	3	0
	4		538.0	454.0	Abandoned		
	5		585.0	1,096.4	471	18	12
	6		431.3	1,076.55	224	13	8
	7		566.8	1,120.14	190	16	11
	8						
	9		532.2	371.2			
San Telmo	1	Lot No. 1	495.0	673.0	Abandoned	4	4
Sanandita	1	Lot No. 7	990.0	615.0	450–500	11	9
	2		988.0	602.9	530	8	4
	3		900.4	734.3	55	11	6
	4		964.4	1,338.1	Abandoned	11	4
	5		932.0	795.5	Abandoned	1	1
Caigua	1	Lot No. 8	1,114.3	1,433.8	Abandoned	11	9
Camatindi	1	Bonaparte	1,442.0	1,252.7	148	9	10
	2	Bonaparte	1,348.1	1,464.6	113	5	6
	3	Pioneer	1,540.9	714.7	120	4	3
Machareti	1	Ayacucho	632.0	1,120.7	Abandoned	5	6
	2	Ayacucho	817.5	1,253.3	Abandoned	10	7
Buena Vista	1	Ayacucho	805.0	964.7	250–500	13	5
Gambeiti	1	Lagunillas	1,036.9	804.7	Abandoned	dry	
Camiri	1	Lagunillas	1,040.6	1,005.8	370	7	5
	2	Lagunillas	1,044.2	451.1	Abandoned		
	3	Lagunillas	1,048.0	943.0	370	2	
	4	Lagunillas	743.7	473.7	5 million cu. ft. of gas		3
Saipuru	1	Parapeti	930.0	682.7	60–70	3	3
	2	Parapeti	934.0	632.5	Abandoned	3	
Guariri	1	Tacurú	1,175.9	512.4	Abandoned	2	3
Tatarenda	1	Tacurú	860.0	981.5	Abandoned temporarily		6

territory, the refineries were asked to increase production to meet the demand for petroleum products by the Bolivian Government and now for the first time are producing on a commercial scale, to supply part of the needs of the Bolivian National Army defending that region.

As explained before, the Standard Oil Co., which developed the southern portion of the Sub-Andean oil zone, has not yet tried to work this territory in a commercial or industrial sense but merely to explore the area in order to determine its possibilities.

TABLE 2.—*Analysis of Three Samples of Bolivian Oil*

	Sanandita No. 3	Camatindi No. 1	Bermejo No. 2
Gravity: deg. Bé. at 70° F.	30.6	44.2	25.6
Deg. Bé. at 60° F.	29.6	43.2	24.6
Viscosity: kinematic at 100° F.	0.127	0.044	
at 130° F.	0.094	0.030	
at 210° F.	0.046	0.024	
Engler at 50° C.	84 sec.	83 sec.	75 sec.
at 100° C.			63 sec.
Calorific value, B.t.u. per lb	18,865	18,600	
Sulfur, per cent	1.47	0.18	
Flash point (Cent.) at 70° F.	30° C.	Less than 10° C.	
at 60° F.			67° C.
Distillation (Cent.) Over point	60	50	57
End point	277	300	188
Per cent distillation	31	64	67
Color (all with greenish fluorescence)	Reddish brown	Dark amber	Dark greenish brown

This tends to explain why the company, in several instances, after having proved areas as productive has temporarily abandoned them to test other fields after drilling a few wells. This policy has resulted in the slight and sporadic development of several fields disseminated in a very large area and similarly has delayed the creation of a real commercial production in one or two long proven fields. A chart of the company's drilling operations is given in Table 1. It is probable that in the near future this company and others will start large-scale production rather than continue wildcatting, since the area, as a whole, has been already proved to be productive.

Almost all of the oil found in Bolivia is of paraffin or mixed base. Analyses of three samples of oil are shown in Table 2.

ACKNOWLEDGMENTS

For assistance in the preparation of this report the writer wishes to express his thanks to the staff of the Standard Oil Co. of Bolivia and to Mr. Gordon Barbour, geologist.

Oil and Gas Developments in Burma, 1934

By L. Dudley Stamp*

(New York Meeting, February, 1935)

In my last report on Petroleum in Burma and India[1], details were given of production and development up to 1932. It was pointed out that the only statements available for Burma were those published officially by the Government of India in the Annual Review of the Mineral Production of India (Records of the Geological Survey of India), which are issued about 10 or 11 months after the close of the year. Operations in Burma are almost entirely in the hands of three companies—the Burmah Oil Co., the British Burmah Petroleum Co. (with its subsidiary, the Rangoon Oil Co.) and the Indo-Burma Petroleum Co.—and these companies preserve a policy of secrecy, so that details are not available of new wells, depth, wells abandoned, or of other figures, except in so far as the Government considers it advisable to publish the information in its possession.

General Developments in 1933–1934

As predicted in 1933, there have been no spectacular developments and no new fields have been discovered. Nor are there any new indications of a likelihood of fresh discoveries. The policy of extremely careful exploitation has been continued and intensified; production is being maintained at an almost steady level and can be so maintained for many years to come—indeed, it is the policy of the leading company to permit refinery and local market requirements to dictate the production required. Contrary to experience in practically every other part of the world, India has shown a slightly decreased demand for petroleum products—especially kerosene, but also for gasoline. The increased use of electricity would explain the lower demand for kerosene, but the falling off in the demand for gasoline can only be attributed, according to the Chairman of the Burmah Oil Co., to the depression and to the incidence of heavy taxation.

In India (including Burma) as a whole, production was 305,018,751 Imperial gallons in 1931 (8,714,822 U. S. barrels); 308,606,031 Imp. gal. in 1932; 306,009,022 in 1933 and is estimated at 308,000,000 in 1934.

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[1] *Trans.* A.I.M.E. (1933) **103,** 404.

Of these totals Burma contributed 243,914,568 Imp. gal. in 1931, 247,570,295 in 1932, 249,000,899 in 1933, and an estimated total of 250,000,000 in 1934.

The main recent advances in Burma have been in connection with the utilization of gas to increase production. The fundamental principle is to make adjustments at each well to secure a maximum oil recovery with a minimum gas production. Wells with high gas-oil ratios are shut in; surplus gas produced at other wells is used either for repressuring or is returned to dry gas sands for storage. An important development has been the recovery of gasoline from gas—the production from this source now exceeds 8,000,000 gal. annually. Oil-field practice throughout Burma is strictly controlled by the Government, through the office of the Warden of the oil field. In the "reserved" area (the area of competitive drilling) in the Yenangyaung field the operation of the vacuum system is permitted. In 1933, the vacuum allowed was increased to 7½ in. of mercury and later to 10 in., while a further increase came into operation in 1934.

TABLE 1.—*Oil in Burma during* 1934

(Barrels of 42 Gallons)

Field	Age, Years to End of 1934	Area Proved, Acres Estimated	Total Oil Production					Number of Wells, January, 1934
			To End of 1933	1921–30, Average	1932	1933	1934, Estimated	
Indaw	17	160	850,000	53,400	115,448	87,222	80,000	45[c]
Yenangyat	42[a]	[b]	6,430,000	56,200	95,876	120,713	110,000	180
Lanywa	11	500	2,378,500		563,200	550,200	600,000	40[c]
Singu	33	2,700	61,606,675	2,670,800	2,541,200	2,360,375	2,238,600	448
Yenangyaung	47[a]	900	103,096,700	4,357,600	3,634,050	3,876,740	3,900,000	3,017
Minbu	25	[b]	2,493,450	140,550	110,020	106,236	100,000	351
Padaukbin and Yenanma	13	40	349,000		13,266	12,416	11,000	
Akyab and Kyaukypu		[b]	28,900	550	378	410	400	
Totals			177,232,148	8,349,750	7,073,438	7,114,310	7,140,000	

[a] Drilled wells.
[b] Production is from small scattered areas in a petroliferous tract.
[c] Estimated.

Statistics on production of oil in Burma are given in Table 1.

OIL FIELDS

Indaw.—This small field showed a considerable drop in production in 1933, but economy in operation was effected by introducing the automatic gas-lift system, now extended to nearly all the wells. The drop in production is largely due to restriction.

Yenangyat.—There are no new developments in this small old field.

Lanywa.—This remarkable field, operated by the Indo-Burma Petroleum Co., Ltd., is situated on a sand bank of the Irrawaddy River, formerly covered during the high water season. The sand bank was enclosed by a retaining wall built in 1925–1929 and continued progress has been made in filling the area behind the wall so as to make the land permanently above high water level. In 1933 the production of 1932 was maintained and the wall was extended to enclose a further productive area on which drilling took place in 1934. Back-pressures are maintained on nearly all wells. All wells are pumped by electricity and there is an efficient plant for the recovery of gasoline from gas.

Singu.—The northern part of this field is operated by the Burmah Oil Co., and lies on the Irrawaddy opposite the Lanywa field. It is certain that there is something like 400 acres of extremely rich oil land connecting the two fields under the river. The schemes for tunneling under the river and erecting derricks in the tunnels have been abandoned and the Burmah Oil Co. now has in hand the construction of an embankment and the dredging of a deep channel so as to confine the river within narrow limits. The dredge was purchased in 1934. The production from the Singu field is varied from year to year to supplement as required the supplies from Yenangyaung, the whole being pumped 300 miles to the refineries near Rangoon. At the southern end of the field is the tract worked by the British Burmah Petroleum Co. The deepest well in Burma (over 6000 ft.) is in this area; it yielded inconclusive results but another test is to be made. At the beginning of 1934 there were 448 producing wells on the whole field, but it is indicative of the policy followed in Burma that a number of wells have been drilled to within a few feet of productive sands and can be deepened literally at a moment's notice. Similarly, the wells with high gas-oil ratios are shut in, and among the experiments in progress are various ones in repressuring by gas drive and air drive, while continuous gas-lift is used on some wells.

Yenangyaung.—The Yenangyaung field continues to be one of the most wonderful fields in the world, despite the fact that it has been worked for over 100 years and intensively by modern competitive methods for the last 30. The production for the year 1933 showed a 7 per cent increase over 1932 and a slight increase is anticipated in the scheme for 1934. At the beginning of 1934 there were 3017 producing wells, including 180 Burmese hand-dug wells. The realization of the importance of a slight asymmetry had led to new drilling and production on the eastern flank, and the known limits of the field have been extended. In the "reserves," which are worked competitively, the vacuum system, controlled by the Government Warden, is used; also repressuring. In the leased blocks successful gas drives are used, dry holes being used for the input of gas. The value of the strikes far in the south of the field is as yet uncertain, and the oil struck in 1932 may only be a small local accumulation.

While cable-tool drilling is still widely employed in Burma, including the Yenangyaung field, during 1933 and 1934 competitive drilling of deep tests by rotary methods was undertaken, especially in the "reserves" at Yenangyaung. Pressure equipments have been used and great attention paid to the character of mud fluid available in connection with the problem of cementing deep wells under high pressures. It seems certain from the experiments that a high-pressure water sand cannot be "mudded off" by nonchemical methods.

Minbu.—There is no new activity to record, the 351 wells in operation in January, 1934, giving an average production of less than one barrel a day each.

Outfields.—The small outfields show a decreasing production. The depression resulted in little activity in exploration. Despite numerous previous failures to locate new fields south of the main producing tract, the Burmah Oil Co. continued with a new deep test at Monatkon.

Oil and Gas Developments in Canada during 1934*

By G. S. Hume†

(New York Meeting, February, 1935)

The production of petroleum in Canada is relatively small in proportion to the amount of oil consumed. Production figures are given in Tables 1 and 2, which show that the production in Alberta for 1934 was more than for the whole of Canada in 1933. The production of natural gas for Canada is shown in Table 3.

Table 1.—*Production of Petroleum in Canada*
Barrels of 42 U.S. Gallons

	1934	1933	1932
Alberta	1,265,940	995,832	906,751
Ontario	141,326	136,058	130,343
New Brunswick	11,545	8,835	6,408
Northwest Territories	4,438	4,608	910
Total	1,423,811	1,148,916	1,044,412

Table 2.—*Production of Petroleum in the Province of Alberta*
Barrels of 42 U.S. Gallons

	1934	1933	1932
Turner Valley: naphtha	1,210,766	963,082	868,812
Turner Valley: light crude	21,896		
Red Coulee: light crude	20,989	31,057	33,256
Wainwright: heavy crude	11,779	5,276	4,683
Skiff: heavy crude	510		
Total	1,265,940	999,415	906,751

In Turner Valley, the largest producing gas and oil field in Alberta, seven naphtha wells from the Paleozoic limestone and one crude oil well from Lower Cretaceous strata were completed during the year. Six-

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* Published by permission of the Director, Bureau of Economic Geology, Department of Mines, Canada. Manuscript received at the office of the Institute Feb. 11, 1935.

† Bureau of Economic Geology, Department of Mines, Ottawa, Ont.

TABLE 3.—*Production of Natural Gas in Canada*
Thousand Cubic Feet

	1934	1933	1932
Saskatchewan	13,781		
Alberta	14,404,281	14,923,597	15,370,968
Manitoba	600	600	600
Ontario	6,810,957	7,163,895	7,386,154
New Brunswick	607,438	618,033	662,452
Total	21,837,057	22,706,125	23,420,174

teen new wells were started, most of which were in the south end. Eleven wells were abandoned, of which one was the famous Royalite No. 4 well that discovered the naphtha production in the Paleozoic limestone in the autumn of 1924. According to Calder (Department of Lands and Mines, Alberta), "from the commencement of production at Royalite No. 4 to the end of December, 1933, the total quantity of naphtha recovered in the Turner Valley area amounted to 6,453,088 bbl., of which approximately one-fifth came from Royalite No. 4 alone." With the decrease in pressure, which in one thickly drilled part of the field has dropped below 500 lb., the Smith separators used to extract the naphtha from the gas are not nearly so efficient as at higher pressures. In 1933 the Royalite company built an absorption plant capable of handling 100,000 M. cu. ft. of gas per day and another plant of similar kind has been constructed in 1934 in the southern part of the field by the Gas and Oil Products, Ltd. The recovery of naphtha has been considerably increased by these absorption plants.

Outside of Turner Valley, within the foothills, no new developments of any significance have occurred during the year. Several wells are in various stages of drilling but progress has been slow and no new completions have been made.

On the plains the most significant event during the year was a show of oil with a considerable volume of gas encountered in the Ranchmen's well, 20 miles east of Turner Valley in the Alberta syncline. This well commenced drilling in Tertiary nonmarine beds and is believed to have almost reached the top of the Lower Cretaceous at slightly more than 6200 ft. depth where the show of oil occurred. It is probable that a further depth of more than 1000 ft. will be required to put the well in the Paleozoic limestone. The oil obtained in this well has a gravity of 48° A.P.I. This show of oil has led to a considerable search for anticlinal structures in the area east of the foothills on the west flank of the Alberta syncline and it appears probable some drilling may result. The area is largely covered by drift except along the major drainage courses, and structures will have to be outlined by geophysical methods.

The year 1934 has witnessed the completion of the first commercial gas well to be drilled in Saskatchewan. The well is near the town of Lloydminster on the Alberta-Saskatchewan boundary and 20 miles south of the North Saskatchewan River. At 1974 ft. this well gave a flow of 16,750 M. cu. ft. per day with a closed pressure of 565 lb. The producing horizon is in Lower Cretaceous beds. The extent of the producing area has not yet been determined, as the area is largely covered by drift. The structure may be the northward extension of the Ribstone field discovered by the Geological Survey of Canada a few years ago. The Ribstone field yielded some oil but the amount was too small to justify extensive development and the field was abandoned.

In Ontario the search for new supplies of natural gas has continued with considerable success in the southwestern Peninsula bounded by lakes Huron, Erie and Ontario. The Dover field has been extended by new wells yielding as much as 4500 M. cu. ft. a day. This field is probably due to a fracture zone in the Trenton limestone and production is obtained at a depth of 2900 to 3200 ft.

In Raleigh township, Kent County, new drilling has extended the DeClute field, where production is obtained in the Silurian at a depth of about 1600 ft. Drilling has been successful also in the Eden field south of Tillsonburg in Bayham township, Elgin County and in Middleton township, Norfolk County.

Petroleum Development in Colombia during 1934

By O. C. Wheeler,* Member A.I.M.E.

(New York Meeting, February, 1935)

There was an increased amount of activity in the oil business in Colombia during 1934 over that of the past several years in point of production, development and exploration. The Tropical Oil Co. continued to be the only company operating on what may be called a commercial basis, although the Gulf, through its subsidiary, the Colombian Petroleum Co., was actively engaged in exploratory and developmental work on its Barco property in eastern Colombia. The Socony Vacuum interests acquired an option from Sr. Luciano Restrepo on a concession in Las Monas-Sogamoso River area and carried out geological investigations on these lands during the year.

Colombian Petroleum Company

The activities of the Gulf in exploration and development in Colombia during 1934 were confined to the Barco concession. The following information is furnished through the kindness of Mr. E. S. Bleecker, Chief Geologist of the South America Gulf Company.

Two strings of tools were kept in operation throughout the year on the Petrolea (Tarra) structure. Three wells were completed, including one deep test, all of which were producers from one or more of the three zones which have been defined in the Lower Cretaceous limestone formation.

On the Rio de Oro structure, some 45 miles northwest of Petrolea, a complete camp has been established on the Catatumbo River, about

Table 1.—*Oil and Gas Production in Colombia*

Line Number	Field, Department	Age, Years to End of 1934	Area Proved, Acres
			Oil
1	Infantas, *Santander*	16	5,300
2	La Cira, *Santander*	8	4,700
3	Petrolea, *Santander del Norte*	2	*x*
4	Rio de Oro, *Santander del Norte*	14	
5	Las Monas, *Santander*	7	*x*

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* Geologist, International Petroleum Co. Ltd., Toronto, Ont.

30 km. above the mouth of Rio de Oro, and from this point a road is being constructed to a drilling location approximately 6.5 km. distant. This road is nearing completion and drilling probably will begin on the structure within the next month or two.

In its operations on the Barco property, the Gulf is seriously handicapped by difficulties of transportation and of operation in a country covered with jungles. Materials are brought in by way of Venezuela by means of river boats and barges on the Catatumbo River, which is navigable only about two months out of the year, during the period of maximum rainfall.

TROPICAL OIL COMPANY

Operations on the Tropical's De Mares Concession were of a routine nature and were confined to the two producing fields at Infantas and La Cira. The total production for the year amounted to 17,340,724 bbl., of which 552,029 bbl. was petroleum condensate extracted from processed gas. There were 30 wells completed, with an average initial production of 665 bbl. from 28 that were tested. No dry holes were drilled. Five strings of tools were in operation at the end of the year.

STATISTICS

Statistics on drilling operations and oil and gas production in Colombia are restricted in Tables 1 and 2 to areas being developed during 1934, with the exception of Las Monas area, which is included to show certain data obtained from Mr. E. S. Bleecker that were not available in previous years. For details on similar operations in previous years in other parts of Colombia, the reader is referred to the report in TRANSACTIONS, volume 107.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.			
	To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily during Nov., 1934	To End of 1934	During 1933[1]	During 1934	Maximum Daily during 1934
1	92,952,184	7,217,655	9,025,665	26,544	17,538	*y*	84	*x*	9,166	*y*	*x*
2	56,517,700	5,939,986	8,315,059	27,911	12,025	*y*	190	*x*	6,356	*y*	*x*
5											
6	*x*	0	0	0	*x*	*x*	*x*				
5	*y*	*y*	*y*	*y*	*x*	*x*	*y*				

[b] Footnotes to column headings and explanation of symbols are on page 249.

[1] Estimated or approximate.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells: Completed to End of 1934	Completed during 1934	At End of 1934: Temporarily Shut Down	Producing Oil Only	Total Producing	Average Depth, Ft.: Bottom of Productive Wells	To Top of Productive Zone	Oil Production Methods at End of 1934, Number of Wells: Flowing	Pumping	Gas Lift	Injection into Reservoir[d]	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of 1933	1934	Character of Oil Approx. Average during 1934, Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	451	2	241	400	400	1,000–2,600	400–2,200	45	324	31	39	x	x	y	37	24	27	0.90	A
2	243	28				600–3,600	400–3,300				13	x	x	y	28	20	25	0.90	A
3	4	3	0	0	0	1,906	1,030		shut in			x	x	x	47	40		0.2	P
4	1[2]	0			0	900	x				x	x	x	x	x	x		x	A
5	9	0	y	y	y							x	x	x	y	y		y	A

[2] Abandoned.

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1934: B.t.u. per Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness Average, Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934: Name	Depth of Hole Ft.[j]
1	1,050	A, B and C Zones	Oli, Eoc	S	15–22	300	AF	12	CreU	3,790
2	1,050	A, B and C Zones	Oli, Eoc	S	15–25	50–175	AF	1	CreU	3,536
3	x	1, 2 and 3 Zones	CreL	L	x	x	A	0	CreL	3,007
4	x	y	Eoc	S	x	x	A	1	Eoc	
5	x	y	Eoc, Cre	S	y	y	A	4	CreU	5,434

TABLE 2.—*Summary of Drilling Operations in Colombia*

(Figures in body of tabulation represent number of holes.)

Department	Completed Prior to January 1, 1935								Completed during 1934		Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes							Productive Wells	Dry and/or Near-dry Holes, Total	Productive Wells		
	Total Depth, Ft.						Total					
	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000		(For Details See Table 1)		(For Details See Table 1)	Within Fields	Exploratory
Santander DeMares Concession	2	5	8	3	3	1	22	698	0	30	5	0
Santander Del Norte Barco Concession...							1[1]	3		3	3	

[1] Abandoned producer.

Petroleum Development in France and French Possessions

By H. de Cizancourt*

France

The Pechelbronn (Alsace) field is the only important French producing field. During 1934, development was carried on as in previous years. The total output of this field reached 553,575 bbl. in 1934, showing a slight decrease from the 1933 figures. Of the total, 315,000 bbl. (56 per cent) was extracted by drilling, while 238,875 bbl. (46 per cent) was obtained by means of shafts and galleries.

Exploration of deep Jurassic and Triassic horizons was still in progress at the end of 1934. A deep well reached the Upper Triassic at a depth of 34 m. (2736 ft.). (Information kindly supplied by M. S. Mena, Directeur Technique.)

As mentioned before, the small Gabian field (Herault) is gradually being exhausted. No drilling operations were undertaken in 1934, the small production being restricted to the pumping of old wells.

Two exploration wells, noted as "drilling" at the end of 1933, were completed in 1934; viz., Lavelanet (Ariège) at 3785 ft. and Santenay (Nièvre) at 2578 feet.

French Possessions

Algeria.—No drilling at Tliouanet. Out of a total of 100 wells drilled in the area, only 8 are still producing. No exploration work is reported during 1934 in Algeria.

Tunisia.—Two wells completed; one well drilling at the end of 1934. A total of 11 wells is reported to have been drilled before the beginning of 1935; out of these, 8 were completed before the present program was begun.

Morocco.—Exploration work progressed actively last year. The outstanding event was the coming in of Ts. 26 well at 1243 ft. This well took fire, therefore great difficulties were encountered in the accurate measurement of initial production; the figure of 1500 bbl. of oil given here is a near estimate. Oil flowed accompanied by a great amount of water.

The apparent decrease of drilling operations in 1934 is explained by the increase in field activities after the results of Ts. 26 were known;

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* Compagnie Française des Pétroles, Paris, France.

many wells started during last year were not completed at the beginning of 1935.

Moroccan production in 1934 was about 4000 bbl. These figures have not been entered under "oil and gas production"; the production being entirely due to the results of drilling tests, which have not as yet resulted in actual exploitation.

Madagascar—French Equatorial Africa.—These two possessions appear for the first time in the "drilling operations" statistics. In French Equatorial Africa a first exploration well was completed during 1934; in Madagascar 13 wells completed between 1909 and 1919 have given no results.

A new drilling program was started in 1934. One well was completed, one well was still drilling at the beginning of the present year.

TABLE 1.—*Oil and Gas Production in France and North Africa*

Line Number	Field, *County*	Age, Years to End of 1934	Area Proved Acres, Oil	Area Proved Acres, Total	Total Oil Production, Bbl. To End of 1934	Total Oil Production, Bbl. During 1933	Total Oil Production, Bbl. During 1934	Total Oil Production, Bbl. Daily Average during Nov. 1934
	France							
1	Pechelbronn, *Bas-Rhin*	199	±7,400	7,400	±13,000,000	558,670	553,575	1,340
2	Gabian, *Herault*	11			151,888	3,000	2,955	
	Algeria							
3	Tliouanet	23	± 30	±30	191,117	4,270	2,962	

Line Number	Number of Oil and/or Gas Wells					Average Depth, Ft.	Oil Production Methods at End of 1934				
	Completed to End of 1934	During 1934		At End of 1934			Number of Wells				
		Completed	Abandoned	Producing Oil Only	Total Producing	Bottoms of Productive Wells	Flowing	Pumping	Gas-lift	Air-lift	Mining
1	±4,000	116	64	641	641	1280		641			3 Shafts
2											
3	± 100			8	8		1	7			

Line Number	Character of Oil Approx. Average during 1934					Producing Rock				Structure[j]	Number of dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1934		Reference to Text[k]
	Gravity, A.P.I. at 60° F.													
	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	Name	Age[g]	Character[h]	Porosity[i]			Name	Depth of Hole, Ft.	
1	17	34.4	23.7	0.08	M	Pechelbronn Formation Jurassic and Triasic	Oligocene	S LD		MF	±2000	Lower Triasic	3434	A
2	34.8	37	35.7		P		Triasic	D		A		Paleozoic		
3	39	47.6			P		Miocene	S		D		Cretaceous		

[f] Footnotes to column heads and explanation of symbols are on page 249.

TABLE 2.—*Summary of Drilling in France and French Colonies*
(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1935		Completed during 1934						Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes, Total	Productive Wells	Dry and/or Near-dry Holes					Productive Wells		
			Total Depths, Ft.				Total			
		(For Details See Table 1)	300–1000	1000–2000	2000–3000	3000–4000		(For Details See Table 1)	Within Fields	Exploratory
France										
Pechelbronn							64	52	41	
Gabian								0		
Other Counties					1	1	2	0	0	0
Morocco			3	2	2		7			6
Tunisia	11			1	1		2			1
Madagascar	14			1						1
Gabon (French Equatorial Africa)	1			1						1

Petroleum Development in Germany during 1934

By WALTER KAUENHOWEN[*]

(New York Meeting, February, 1935)

THE production of crude oil in Germany during 1934 totaled about 2,200,408 bbl., a 33 per cent increase over the 1,670,109 bbl. produced in 1933. This is an extension of a yearly increase which has continued uninterruptedly since 1928.

TABLE 1.—*Oil Production of Germany by Fields and Oil Provinces, 1928–1933*

(Barrels of 42 Gallons)[a]

Year	Salt-dome Province					Thuringian Basin	Total Production of German Reich
	Nienhagen-Hänigsen Field	Wietze-Steinförde Field	Oelheim-Eddesse Field	Oberg Field	Total Salt Dome Fields	Volkenroda Field	
1928	274,323	322,742	679	46,319	644,021[b]		644,315[c]
1929	310,891	337,582	10,535	67,578	719,901[b]		720,069[c]
1930	586,404	427,539	100,716	72,485	1,186,969[b]	29,806	1,220,296[c]
1931	506,548	403,634	213,549	116,088	1,242,598[b]	360,885	1,602,517[c]
1932	769,405	366,982	230,979	130,711	1,498,077[b]	110,481	1,608,558[c]
1933	1,014,853	376,628	127,211	110,131	1,628,823[d]	40,698	1,670,109[c]
1934	1,685,124	363,118	52,001	88,935	2,189,964[d]	10,444[e]	2,200,408

[a] Official figures published in Germany are given in metric tons. For the above conversion into barrels a factor of 1 metric ton equaling 7 bbl. has been used.

[b] Includes a very small production from Heide in Holstein.

[c] Includes a very small production from Tegernsee in Bavaria and Bruchsal in Baden.

[d] Preliminary official figures.

[e] Estimated.

PRODUCING FIELDS

The 1934 increase in production is due chiefly to developments in the north district of the Nienhagen field, where the production in 1934

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[*] Hamburg, Germany.

was 66 per cent greater than in the previous year. In 1934 it furnished 76.9 per cent of the total oil production of Germany. The Wietze field in 1934 contributed 16.7 per cent of German oil production. The output of the field remained rather stable. The Oberg, Oelheim-Eddesse, and Volkenroda fields showed decreases.

WILDCAT ACTIVITIES

The most important feature during the year was the active interest of the German Government in the development of its national oil resources by subsidizing wildcat wells. In March, 1934, the Government appropriated the amount of RM 5,000,000 for this purpose. Under a special plan, subsidies were granted to 57 wildcat wells. Fifty per cent of the drilling costs of these wells is to be paid by the operators and the other fifty per cent is to be advanced as a loan by the Government. The total footage of the subsidized drilling program in its first year is estimated officially at 175,000 ft. Subsidies are granted only for wells that are drilling outside of the proven oil fields.

According to a published official report, 41 wells (including 10 shallow core tests) out of these 57 wildcat wells are located on 14 different salt plugs, 5 wells test other structural highs, 8 wells are drilling in the Thuringian Basins for Zechstein oil, 2 wells explore the fault-trap conditions of the Rhein-Graben in the State of Baden, and one well is drilling in Westphalia on a structural high.

Besides these 57 subsidized wells, at the end of 1934, about 10 not subsidized wildcat wells were drilling in Germany and 30 wells were drilling in the proven fields.

GEOPHYSICAL ACTIVITIES

Geophysical surveying was done by various operators in a routine way, especially in the wildcat territories of northwestern Germany. The German Government is reported to have appropriated during the second half of 1934 the amount of RM 325,000 for a geophysical exploration program. The purpose of this work is to explore the regional geophysical conditions of Germany, especially of the various prospective oil provinces. In carrying out this program seismic, magnetic and gravitational methods are being applied.

Oil and Gas Development in Iraq in 1934*

By Ben B. Cox,† Member A.I.M.E.

(New York Meeting, February, 1935)

During the past year considerable progress was made in the exploitation of Iraq's resources, although no new fields were discovered. The principal development was the completion of the much heralded pipe line from Kirkuk to the Mediterranean, by the Iraq Petroleum Co., Ltd., and the beginning of crude exports to Europe on the second of August. Official ceremonies for the opening of the lines took place in January, 1935. The line in itself is sufficient achievement under the existing natural handicaps to deserve a moment's attention. It is 1151 miles long, composed of two independent lines made up mostly of 12-in. with some 10-in. and 8-in. pipe, and extends from Kirkuk westward 156 miles to beyond the Euphrates River as a double line. From that point, near the village of Haditha inside the Iraq border, it bifurcates, one leg going as a single line to Haifa through the British Mandated Territories of Trans-Jordania and Palestine, and the other to Tripoli through the French Mandates of Syria and the Leban(on)ese Republics. The total length of the Tripoli line is 532 miles, of the Haifa line 619 miles. The line leaves Kirkuk at an elevation of 1013 ft., drops to 350 ft. at the Tigris, to 200 ft. at Wadi Tharthar west of the Tigris and again to 300 ft. at the Euphrates, rises to more than 3150 ft. at mile 451 on the central Arabian steppe along the south line and to more than 2500 ft. at mile 466 along the north line. On crossing the rift valley of the Jordan River south of Galilee, it drops abruptly below 850 ft. below sea level, requiring the use of extra heavy 8-in. pipe and a relief station to reduce the pressure. A picked group of American welders, under H. S. Austin, of the Ajax Pipe Line Co., laid the line. It is coated, wrapped, and buried 30 in. beneath the surface in solid rock along much of the route. It crosses four large rivers and wide stretches of alkaline soils. Twelve pumping stations are employed, three of which are double east of the bifurcation. Each single station houses three 500-hp. crude-burning deisel engines flexible-coupled to reciprocating pumps. Each pumping unit is capable of handling a minimum of 21,000 bbl. of oil, giving the entire system a capacity of 84,000 to 85,000 bbl. per day. Each station is a small township, practically self-contained, with the comfort of the employees well cared for. Ample storage is provided at each sea terminal for the continuous operation of the line. Tankers will be able to load at Haifa in either an oil dock or at one of two sea lines but at Tripoli loading is confined to three sea lines. Sufficient pressure is available at each terminal to load a ship at the rate of 1000 tons per hour. Intercommunicating telegraph, telephone and teletype connect all operations from Kirkuk to the sea. A well made highway has been constructed through the lava country on the southern leg of the line, making communications and patrolling a relatively easy task. The company owns a fleet of airplanes, which may supplement the ordinary patrols. Ten years of constant effort together with the expenditure of very large sums of money by the I.P.C. (T.P.C.) have developed a remarkable field, the largest single-unit operated pipe line in the world, and a complete communications system in a sparsely populated desert region that for the most part is geared to customs and methods of Biblical times. Since April, 1931, the I.P.C. has produced for the treasury of the Iraq Government a minimum sum of $2,000,000 annually without taking account of related increase in trade to that small kingdom or the large employment permanently of its nationals hitherto able to turn only to an uncertain and primitive form of agriculture for their livelihood. Today oil is moving on schedule to European ports. The project as a whole has been an outstanding example of international corporate accomplishment when freed of extraneous interference.

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* Published by permission of the Near East Development Corporation. Manuscript received at the office of the Institute Feb. 20, 1935.

† Geologist, Near East Development Corporation, New York, N. Y.

The Mosul Oil Fields Ltd., following a geological survey of its West Tigris concession last year, began drilling operations through its subsidiary the B.O.D. Ltd. To date it has reopened the low-gravity Qaiyarah-Najmah-Jawan field discovered by T.P.C. (I.P.C.) in 1927 and abandoned by the latter in 1928, and is reported as drilling a deep test on this structure as well as tests on Sadid and Hujara, all of which lie in the Shergat district. Nine wells in all are being drilled. Under its concession with the Iraq Government, it must construct a pipe line to the tide water when 1,000,000 tons per annum potential production has been proved.

The Anglo Persian Company's subsidiary, the Khaniqin Oil Co., Ltd., continued to develop its Transferred Territories field at Naft Khaneh during 1934 and to supply the local Iraq market through the Rafidain Oil Co., Ltd. with products from its refinery near Khaniqin. A further outlet for Naft Khaneh crude will soon be provided, when the pipe line from Naft-i-Shah (the Persian extension of the Naft Khaneh field) to Kermanshah, Persia, which is now under construction, is completed. A refinery is being constructed at Kermanshah.

Oil and Gas Production

Very little gas was produced with the oil during the year and so far no market exists for the gas. Approximately 8,000,000 bbl. of oil was produced during 1934 from all fields and approximately 7,000,000 bbl. was exported, including the crude required to fill the Iraq Petroleum Company's new pipe line.

Iran

(New York Meeting, February, 1935)

According to published reports, controlled production from the Masjid-i-Sulaiman and Haft Kel fields for the year 1934 was as follows:

	Barrels		Barrels
January	4,164,790	July	4,577,251
February	3,988,502	August	4,886,462
March	4,483,535	September	4,955,419
April	4,284,231	October	4,499,530
May	4,648,105	November	3,825,178
June	4,399,045	December	4,049,556
			52,761,604

No new development of major importance in either of these areas is reported.

Owing to the increasing demand in North Iran, particularly for gasoline and kerosene, it has been arranged that this market shall in future draw its supplies from a newly constructed refinery at Kermanshah. This refinery is connected by a 3-in. pipe line, 145 miles long, with the Naft-i-Shah field, on the borders of Iraq and Iran.

The crude oil will pass through a topping plant at the field and the products will be stored and pumped to the Kermanshah refinery in such proportions and quantities as are demanded by actual market requirements.

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Oil-field Activity in Italy during 1934*

(New York Meeting, February, 1935)

The year 1934 saw a very thorough and intensive search for oil in Italy, both by the Government-subsidized company, the A.G.I.P., and by the few smaller operating companies. Approximately two-thirds of the exploration work, however, has been done in the Province of Emilia (northern Italy).

The A.G.I.P. has been particularly active in the Emilia district and has sunk several rotary holes between Voghera and Ferrara on structures located by geophysical means in the Po Valley. Only insignificant amounts of oil have shown up in these tests to date but gas has been found in fair quantities, and apparently the company is not yet prepared to abandon its search in this part of the country without further effort. In Central Italy, the same company has put down four tests with cable tools and of these two were "dry holes" and the other two found only traces of oil. The A.G.I.P. also sank two wells in southern Italy and it is believed that in these the indications were sufficiently encouraging for the exploration work to be continued. No serious drilling has yet been done in Sicily by the A.G.I.P. or any other company. The annual subsidy granted to the A.G.I.P. by the Government for the duration of its five-year plan has been considerably reduced for 1935 and this may interfere with the completion of the coming year's program in all its details.

The Società Petrolifera Italiana, which is the chief producing company in the country, has continued the development of its two fields, Salsomaggiore and Vallezza, and at the same time has intensified its program of exploration. Rotary machinery has been introduced and is undergoing a thorough trial, and prospects of finding new pools at greater depths are considered good. The charcoal adsorption plant at Vallezza has operated satisfactorily throughout the year and has produced nearly 3000 bbl. of high-grade gasoline. Besides the exploration well at Rile dell'Olio, which is still drilling, another wildcat test has been started at Torre-di-Traversetolo. All operations of this company are confined to the district of Emilia.

The Società Petroli d'Italia has continued to operate the old fields of Montechino, Gratera and Velleja, and has a well now exploring at greater depths in that general area. Of the two exploration wells in the Torino district, one has been abandoned at a shallow depth owing to difficult drilling conditions, while the second has also made only moderate progress. The fields of Ripi, S. Giovanni Incarico and Ceccano are probably to be closed down soon. The Government's recent action in reducing the premium on crude produced from the national subsoil has adversely affected the profits of private companies, and it is probable that this is the reason why it is no longer possible to operate these fields in Central Italy on an economical basis.

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* Paper secured through W. P. Haynes, Member A.I.M.E., London, England. Manuscript received at the office of the Institute Feb. 10, 1935.

Although official figures have not yet been issued by the A.G.I.P. and Petroli d'Italia, the year's output of crude, and the footage drilled may be briefly estimated as follows:

Company	Footage Drilled during 1934	Production of Crude, Bbl.	Remarks
Società Petrolifera Italiana...	45,500	117,200	High-grade crude (Emilia)
Società Petroli d'Italia.......	17,000[a]	13,200[a] 3,460	High-grade crude (Emilia) Heavier crude (Central Italy)
A.G.I.P. (Azienda Generale Italiana Petroli.[b]	46,235	18,900	Medium-grade crude from Fontevivo, Podenzano, &c.
Total..................	108,735	152,760	

[a] Estimates based on incomplete data.

[b] The A.G.I.P. figures are based on the Italian financial year; namely, from July 1, 1933 to June 30, 1934.

Petroleum Development in Mexico during 1934

By V. R. Garfias* and R. V. Whetsel,* Members A.I.M.E.

(New York Meeting, February, 1935)

Principal events in petroleum operations of Mexico during 1934 have been the completion of three producing wells in the Poza Rica area and the plans for the expansion of operations of the Cia. de Petroleos de Mexico, S.A. (Petromex). Production for 1934 is estimated at close to 38,000,000 bbl., an increase of 4,000,000 bbl. over the previous year; an increase due in large part to the successful development in Poza Rica. The output of the South fields (Golden Lane) and Tehuantepec fields also increased somewhat during the year. Production of natural gasoline increased from 382,000 to 431,000 bbl. in 1934. Crude run in local refineries is estimated at 26,000,000 bbl., some 4,000,000 bbl. more than the previous year. Exclusive of bunker fuel exports totaled 24,000,000 bbl., or 3,000,000 more than in 1933. Domestic consumption increased approximately 500,000 bbl. during the year, reaching a total of close to 13,600,000 bbl., exclusive of ships' bunkers.

A total of 148 wells were completed as compared to 91 in 1933 and 40 in 1932. In proven areas, 133 completions resulted in 54 producers and 79 failures. The 15 wildcats drilled during 1934 gave no encouraging results. Seven of these were located in the border zone of northeastern Mexico; three tested possible northeast extensions of the Northern fields; two were drilled for possible extensions of the "Golden Lane" and three were completed in the Isthmus of Tehuantepec.

Fields

Northern Fields (*Heavy Oil District*).—There were 34 producing wells and 71 failures completed in the Northern fields, as compared to 20 producers and 20 failures in 1933. Practically all new producers were drilled to the shallower San Felipe formation, while wells drilled to the deeper Tamasopo limestone encountered salt water. Production of the field totaled 11,890,000 bbl., a decrease of 7.5 per cent from the previous year. Acid treatment was attempted during the year in seven wells

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* Foreign Oil Dept., Henry L. Doherty & Co.

without any appreciable success. In some cases tubing and reconditioning of old wells checked the declining trend of production.

South Fields (Golden Lane Area).—During 1933 there was no development on the Golden Lane structure of the South fields. Renewed activity in 1934, however, resulted in five producers and eight failures; new producers added about 1000 bbl. daily to output. Old wells maintained a remarkably steady output and as a result the area in 1934 will produce some 1,814,000 bbl. more than in the previous year.

Poza Rica.—Only three wells with an average depth of 7600 ft. were completed in Poza Rica during 1934. All averaging daily yield about 4000 bbl. each. Since the discovery of the pool late in 1930 it is estimated that an area of about 10 sq. km., or about 2500 acres, has been proven. The reservoir rock is similar to the El Abra limestone in the Golden Lane and the wells produce under high gas pressure. Their initial yield indicates, however, that the ultimate production of the pool per unit area will not be as large as that of the Golden Lane. Three wells were drilling at the close of 1934 that may extend the area of the field. No development has yet occurred that marks the limits of the pool to the south and east. Production in 1934 totaled 3,669,000 bbl., compared to 803,300 in the previous year.

Isthmus of Tehuantepec Fields.—Eleven wells were completed in proven areas during 1934, all of which were producers. In 1933 a total of 37 completions resulted in 29 producers. The 11 completions during the year were more than sufficient to maintain steady output, as production increased from 9,240,000 bbl. in 1933 to 9,580,000 in 1934.

Mier Gas Field (Camargo).—Only one well was completed in the shallow gas field at Mier near the United States border during 1934, with a reported initial capacity of 20,000,000 cu. ft. daily. Gas output and pressure decreased steadily during the year in the four producing wells of the field. The gas from this field is utilized by the City of Monterrey.

TABLE 1.—*Production of Oil in Mexico*

	Production, U.S. Barrels				Number of Producing Wells
	1933	1934	Total since Discovery to End 1934	November, 1934	
Northern fields (11° to 14° A.P.I.)	12,879,000	11,890,000	705,869,000	922,769	595
South fields, Golden Lane (20° to 24° A.P.I.)	10,853,000	12,667,000	986,764,000	1,038,313	241
South fields, miscellaneous	225,000	191,000	4,629,000	14,363	32
Poza Rica (33° to 34° A.P.I.)	803,000	3,670,000	4,667,000	460,616	5
Isthmus of Tehuantepec (32.5° A.P.I.)	9,240,000	9,580,000	59,548,000	889,720	180
	34,000,000	37,998,000	1,761,477,000		

CRUDE OIL PRICES AND TAXES

The price of heavy crude spot cargoes f.o.b. Tampico increased from 74¢ per barrel at the close of 1933 to $1 per barrel by September 1934. At the close of 1934 the price was steady at $1 compared with an average price of 60¢ in 1933; 44¢ in 1932; 55¢ in 1931; 60¢ in 1930; 65¢ in 1929 and $1.05 in 1928.

Southern crude not controlled by local refineries sold as low as 35¢ a barrel at the well during the greater part of 1934. Toward the close of the year, however, prices of such crude began to increase substantially.

Table 2 shows Mexican oil taxes for December, 1933, and December, 1934.

TABLE 2.—*Mexican Oil Taxes*

	Per U.S. Barrel			Per U.S. Barrel	
	December, 1933	December, 1934		December, 1933	December, 1934
Heavy crude.......	$0.10646	$0.11654	Crude gasoline...	$0.27335	$0.26411
Light crude........	0.17196	0.18783	Refined kerosene..	0.08635	0.08419
Fuel oil...........	0.16321	0.16765	Crude kerosene...	0.17709	0.17236
Refined gasoline....	0.12786	0.12344	Lubricants.......	0.14805	0.14850

OUTLOOK FOR 1934

Drilling activity and production in the Northern fields is expected to decline in 1935. New development in Poza Rica and south of the Tuxpam River, however, probably will increase output in these areas, while fields in the Isthmus of Tehuantepec should maintain their present output. It is reasonable to expect that Mexican production in 1935 may reach 40,000,000 barrels.

Netherlands East Indies and Sarawak

(New York Meeting, February, 1935)

The figures given here were received through the courtesy of the Bataafsche Petroleum Maatschappij and the Standard-Vacuum.

There is an increase in production for the year of approximately 4½ million barrels. In November the average production indicated that during the year 1935 the total production would probably exceed 50 million barrels. To maintain this production, only 106 wells were drilled during the year, mainly in South Sumatra.

Table 1.—*Oil and Gas Production in the Netherlands East Indies and Sarawak*

	Administration	Age, Years to End of 1934	Total Oil Production, Bbl.				Average Oil Production, Bbl. per Well Daily during Nov., 1934	Total Gas Production, Millions Cu. Ft.	
			To End of 1934	During 1933	During 1934	Daily Average during Nov., 1934		During 1933	During 1934
1	North Borneo	25	62,896,825	4,277,000	4,682,000	12,790	29	2,375	4,152
2	East Borneo	39	305,864,205	14,252,000	13,562,000	38,090	58	4,099	5,345
3	Ceram	38	4,394,519	262,000	253,000	687	22	36	28
4	Java	47	71,649,013	3,610,166	3,797,962	10,052	22	1,389	1,578
5	South Sumatra	38	157,473,670	16,484,694	18,833,976	52,534	64	2,823	3,174
6	North Sumatra	50	99,796,840	6,079,000	8,342,000	23,749	226	1,721	1,736
7	Total		702,075,072	44,964,860	49,460,938	137,902	53	12,443	16,013

	Number of Oil and/or Gas Wells						Average Depth, Ft.		Oil Production Methods at End of 1934		
	Completed to End of 1934[1]	During 1934		At End of 1934			Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		
		Completed	Abandoned	Producing Oil Only	Producing Gas Only	Total Producing			Flowing	Pumping	Gas-lift + Air-lift
1	512	3		443	1	444	340–5,280	130–5,242	9	413	21
2	1,290 + y	26		661	1	662	230–2,620	210–2,600	13	628	20
3	75	2		31		31	260–1,020	240–1,000		31	
4	1,426 + y	1		473		473	160–2,950	130–2,880	7	462	4
5	1,579 + y	68		441	3	444	290–5,400	160–5,200	160	98	183
6	943 + y	6		105		105	300–4,140	260–4,100	40	33	32
7	5,825 + y	106		2,154	5	2,159			229	1,665	260

[1] Explanation of symbols is on page 249.

Manuscript received at the office of the Institute Feb. 19, 1935.

TABLE 1.—(*Continued*)

	Producing Rock				Structures	Number of Dry and/or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Name	Age[g]	Character	Porosity, Per Cent			Name	Depth of Hole, Ft.
1	Seria—and Miri formations	Mio	SsH	18	AF	80	Miri deep shale	6,180
2	Balik Papan + Poeloe Balang and Tarakan formation	Pli + Mio	SsH, S	10–30	Af	199 + y	Poeloe Balang zone	5,250
3	Boela formation + Triassic	Pli + Tri	SsH	y	Af	40	Triassic	2,400
4	Mergelklei—Globigerinae—Orbitoïd zones	Pli + Mio	S, SH, LS	15–35	Af	308 + y	Basismergelzone	5,900
5	Palembang—and Telissa zone	Pli + Mio + Paleogene	S, SH, SS	13–28	Af	344 + y	Under Telissa zone	7,550
6	Seuroela—Keutapang—Grensklei zones	Pli + Mio	S, SH, SS	y	Af	242 + y	Grensklei zone	6,680

TABLE 2.—*Summary of Drilling Operations in the Netherlands East Indies and Sarawak*

Administrations	Completed Prior to Jan. 1, 1935										Completed during 1934							Drilling or Incomplete at End of 1934	
	Dry and/or Near-dry Holes									Productive Wells (For Details ,See Table I)	Dry and/or Near-dry Holes						Productive Wells (For Details see Table 1)		
	Total Depth, Ft.										Total Depth, Ft.								
	0–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000	Total		0–1000	1000–2000	4000–5000	5000–6000	6000–7000	Total		Within Fields	Explanatory
North Borneo	30	27	16	7	3				83	505							3	1	1
East Borneo	92 + y	74 + y	25 + y	4 + y	2	2			199 + y	1244 + y		3				3	26	7	1
Ceram	34	4	2						40	75							2		
Java	217 + y	75 + y	10 + y	3 + y	1	1	1		308 + y	1348 + y		1			1	2			1
South Sumatra	200 + y	108 + y	21 + y	8 + y	3	2	1	1	344 + y	1579 + y	1	2	1	1		5	20	3	1
North Sumatra	153 + y	49 + y	33 + y	2 + y	2	2	1		242 + y	712 + y							6		1

Petroleum Development in Peru during 1934

By Oliver B. Hopkins,* Member A.I.M.E.

(New York Meeting, February, 1935)

The Peruvian production increased over 3 million barrels from 1933 to 1934—from approximately 13¼ million barrels to over 16¼ million barrels—bringing the cumulative production of the country up to 171 million barrels. Most of this production, as well as most of the increase in 1934, came from La Brea-Parinas Estate, the property of the International Petroleum Co., Limited. In 1932 Peru stood eleventh among the oil-producing countries of the world, but in 1933 her production exceeded that of Trinidad, Argentine and Colombia, which placed her in eighth position. In 1934 Peru's production was exceeded by that of Colombia by about one million barrels, and by that of the Argentine by about 1½ million barrels, thus placing her in tenth position. After several years of relative inactivity in drilling and exploration there was a noticeable increase during 1934 in both of these lines of activity.

Oil Fields

La Brea-Parinas Estate.—Production on the La Brea-Parinas Estate reached a significant total of 85,080 bbl. as early as 1891. It increased to over one million barrels in 1912, and to over 10 million barrels in 1929, and in 1934 it reached an all-time high of over 14 million barrels. The total production from 1890 to 1934 was 133,784,609 barrels.

Practically all the drilling on the property has been done with cable tools, but during 1934 three strings of rotary tools were introduced. One was a heavy outfit for drilling a deep test and the other two were lighter outfits for deepening wells in the newer section of the field, where the gas pressure was too high to permit safe drilling with standard tools.

During 1934 a total of 28,127 ft. was drilled, 66 wells were deepened, and 6 new wells were completed. At the end of the year 2844 wells had been drilled on the Estate, of which 1814 were still productive. The remaining 1030 wells represent abandoned producers or dry holes. The total area that has been productive up to the present time is estimated at 13,369 acres.

An interesting article on the various phases of operations of the International Petroleum Co. was written by Arthur Iddings and published in *The Oil and Gas Journal* (Dec. 27, 1934).

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The Lobitos Property.—The Lobitos property, operated by La Compania Petrolera Lobitos, consists of 141,140 acres along the coast north of the La Brea-Parinas Estate. There are two producing fields on this property, one at Lobitos and the other about 15 miles farther north, at Cabo Blanco and Restin. From 1905 to the end of 1934 these fields produced slightly under 34 million barrels. To the end of 1933, there had been drilled 827 wells, of which 580 were producers at that time. The average depth of the wells is approximately 2200 ft. and the production comes from the Eocene and Oligocene, or, generally speaking, from beds of the same age as are productive on the La Brea-Parinas Estate. The productive area amounts to approximately 7000 acres, and the average yield per acre has been about 5000 barrels.

Zorritos Property.—Piaggio & Co., operating at Zorritos, controls an area of 951 pertenencias, or approximately 7315 acres, on which 380 wells, with an average depth of approximately 1500 ft., had been drilled up to Dec. 31, 1933, and from which approximately 2,993,689 bbl. of oil had been produced to the end of 1934. During 1934 some 35 to 40 wells were producing, and are reported to have yielded during that year 47,668 barrels.

Very little drilling has been done on this property in recent years and no notable extensions have been made to the productive area, which amounts to about 300 acres. All the production has come from beds considered to be of Miocene age. The first production of 5501 bbl. from the property was reported in 1884. The highest production was obtained in 1910, when 107,000 bbl. was produced. The yearly production during the past five years has been approximately one-half of that obtained during 1910.

TABLE 1.—*Oil and Gas Production in Peru*

Line Number	Field, *Department*	Age, Years to End of 1934	Area Proved, Acres		Total Oil Production, Bbl.			
			Oil	Total	To End of 1934	During 1933	During 1934	Daily Average during Dec., 1934
1	La Brea and Parinas, *Piura*........	45	13,500	13,500	133,784,609	11,205,362	14,130,102	39,885
2	Lobitos and Restin, *Piura*.........	30			33,944,213	1,994,700	2,101,340	6,000
3	Zorritos, *Tumbes*.................	51			2,993,689	57,256	47,668	131
4	Pirin (Huacane), *Puno*............		Operations abandoned in 1915		285,936	0	0	0
	Total..........................				171,008,447	13,257,318	16,279,110	

Development of Oil and Gas in Poland during 1934

By Charles Bohdanowicz*

As in preceding years, the most intensive drilling activity during 1934 took place in the old fields of the western part of the Polish Carpathian petroleum province (district of Jaslo). The number of wells completed to the end of 1934, expressed in percentages, is as follows: Jaslo district, 57 per cent; oil fields outside Boryslaw-Tustanowice-Mraznica, 27; Stanislawow district 8 and Boryslaw fields only 7 per cent. The number of meters drilled (Table 2), expressed in percentages, for the same fields are as follows: Jaslo district, 51 per cent; oil fields outside Boryslaw-Tustanowice-Mraznica, 26; Stanislawow district, 12, and Boryslaw oil fields, 11 per cent. This comparison shows that most of the new

Table 1.—*Oil and Gas Production in Poland*

Line Number	Field, *County*	Age, Years to End of 1934
	Jaslo district	
1	Domin. Kob. Lib. Lip. Kryg., *Gorlice*	70
2	Biecz, Biecz-Korczyna, *Jaslo*	37
3	Harklowa, *Krosno*	64
4	Roztoki, Jaszczelv. Brzez Sądk., *Jaslo-Krosno*	25
5	Potok, *Krosno*	43
6	Toroszówka, *Krosno*	44
7	Krosno-Krościenko, *Krosno*	46
8	Zmiennica-Turzepole-Strachocina, *Brzozów*	38
9	St. Wieś-Grabownica-Humniska, *Brzozów*	38
10	Węglówka, *Krosno*	46
11	Bobrka-Rowne-Rogi-Wietrzno, *Krosno*	76
12	Lubatowka-Iwonicz-Wólka, *Sanok*	46
13	Mokre, Tyrawa Solna-Zagòrz, *Sanok-Lisko*	53
	Total Jaslo	
	Drohobycz district Median zone	
14	Wankowa-Lieszczowate, *Lisko*	48
15	Ropienka-Paszowa, *Lisko*	49
16	Rajskie-Polana, *Lisko*	48
17	Strzelbice, *Stary-Sambar*	51
18	Schodnica-Urycz, *Drohobycz*	53
	Marginal zone	
19	Boryslaw-Tustan.-Mraznica, *Drohobycz*	48
20	Rypne-Duba, *Dolina*	47
	Total Drohobycz	
	Stanislawow district	
21	Rosulna-Majdan, *Bohorodczany*	45
22	Bitków, *Bohorodczany*	36
23	Pasieczna, *Nadwórna*	66
	Total Stanislawow	
	Other Fields	
24	Daszawa-Gelsendorf-Opary, *Stryj*	13
25	Other fields	
26	Total Poland	

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* Professor of Economic Geology, Warsaw, Poland.

wells, not only the deepened old wells, are in the Jaslo district and in the fields outside Boryslaw-Tustanowice-Mraznica.

TABLE 2.—*Total Meters Drilled, Poland*

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawow	Total
1934	38,080	19,480	8,219	8,824	74,603
1933	32,382	19,418	7,582	7,519	66,901
1932	25,267	17,690	8,063	7,458	58,478
1931	28,666	20,749	14,444	10,653	74,512
1930	38,551	30,251	28,616	19,180	116,598

A comparison of the annual figures showing the number of new wells started in each year from 1930 to 1934 (Table 3) shows that the number of these wells in 1934 almost reached the level of 1930 only in the district of Jaslo, whereas in all the other districts there was a marked decrease.

TABLE 1.—(*Continued*)

Line Number	Area Proved, Acres				Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.			
	Oil	Oil and Gas[a]	Gas	Total	To End of 1934	During 1933	During 1934	Daily Average during Nov. 1934	Per Acre to End of 1934[b]	Per Acre-foot to End of 1934	Per Well Daily in Nov. 1934	To End of 1934	During 1933	During 1934	Max. Daily during 1934
1	1,062			1,062	4,064,154	143,190	142,154	425	3,827		1.1				
2	54			54	280,904	24,124	30,118	93	5,202		3.1				
3	124			124	1,632,958	73,260	64,898	181	13,169		1.4				
4		74	332	406	219,594	29,008	33,670	107	2,967		9.7	59,665[1]	1,855	3,090	9.0[3]
5		173		173	4,755,832	87,320	67,192	166	27,500		3.2				
6		99		99	222,616	18,944	26,196	91	2,250		5.4				
7	86			86	951,171	42,328	38,702	104	11,060		2.3				
8	67		307	374	628,016	19,980	19,980	52	9,373		1.4	566	122	111	3.0[4]
9		296		296	1,671,438	107,152	110,038	271	5,647		5.8	?	455	521	1.8
10	156			156	1,905,722	28,860	26,862	32	12,210		0.4				
11		198		198	5,311,868	85,100	74,888	234	26,828		3.1				
12	185			185	1,734,856	22,200	32,856	87	9,380		1.3				
13	50			50	1,166,750	1,776	8,954	39	23,355		2.6				
					24,545,879	683,242	676,508					60,231	2,432	3,722	
14	220			220	4,109,315	123,825	111,740	400	18,680		2.9				
15	74			74	1,406,652	25,125	31,302	86	19,000		0.7				
16	40			40	58,981	3,375	3,256	14	1,474		1.4				
17	75			75	568,468	22,348	19,610	58	7,580		1.7				
18	716			716	18,880,012	345,210	344,396	930	26,368		1.8	(1916–1934)			
19	2,816			2,816	173,839,542	2,392,732	2,251,524	6,251	61,733		12.0	177,821[2]	5,950	5,381	6.0[5]
20	150			150	1,814,406	152,440	166,130	466	12,096		4.4	?	450	463	4.8
					200,677,376	3,065,055	2,927,958					177,821	6,400	5,844	
21	75			75	289,424	23,680	23,616	66	3,860		1.2				
22	250			250	5,545,166	172,748	189,218	613	22,181		6.4	24,090	1,435	1,410	3.9
23	150			150	725,694	32,832	29,002	87	4,838		3.0	?	142	124	
					6,560,284	229,260	241,836					24,090	1,577	1,534	
24			650	650								(1924–1934) 33,858	4,282	6,576(?)	18.0
25					?	113,163	71,255								
26					231,783,539	4,090,720	3,917,557					296,000	14,691	17,676	

[a] Footnotes to column headings indicated by letters and explanation of symbols are on page 249.
[1] According to Dr. Tolwinski 34,519.
[2] According to Dr. Tolwinski.
[3] For all fields in this area.
[4] New well Górki.
[5] For Tustanowice field.

TABLE 3.—*Number of New Wells Started during Each Year*

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawow	Total
1934	81	24	5	8	118
1933	66	42	5	4	117
1932	58	31	4	7	100
1931	76	36	8	14	134
1930	86	68	13	28	195

The number of producing wells (Table 4) has varied very little since 1930, except that in the Boryslaw fields it somewhat increased in 1933 and 1934 because a number of wells were deepened or reconstructed.

TABLE 4.—*Number of Producing Wells*

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawow	Total
1934	952	1,126	884	211	3,173
1933	1,177	1,047	639	263	3,126
1932	1,119	1,026	624	267	3,036
1931	1,085	999	619	273	2,976
1930	1,015	993	633	278	2,919

TABLE 1.—(*Continued*)

Line Number	Completed to End of 1934	Number of Oil and/or Gas Wells							Average Depth, Ft.		Oil Production Methods at End of 1934					
		During 1934		At End of 1934							Number of Wells					
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Miscel. (Swabbing)	Injection into reservoir[d]
1	781	31	38	8	377		2	379	900–1,500	600		379			25	3
2	44	5		12	30			30	1,280	1,160		30				
3	261	8			127		1	128	1,000	700		123			4	6
4	47	5		1	3	8	21	32	3,000	±2,900					8	
5	182			1	51			51	2,200–2,800	±2,200		51				12
6	49	4			17			17	600–1,000	500–900		17				
7	107	1			46			46	1,300	1,000		46				
8	59	1		4	36		2	38	1,000	450		30			6	
9	102	3	3	6	45			45	1,800	1,600		28			17	
10	221	1		2	79			79	820	660		79				
11	244	3		4	74		2	76	1,320–2,200	1,000–1,300		51			23	
12	75			5	67			67	1,300	1,200		64			3	
13	54	2		3	15			15	1,400			15				
	2,226	64	41	46	967	8	28	1,003								
14	185	6		11	174			174	1,450–1,600	± 960		174				
15	153	6			115			115	1,050–1,200	± 900		115				
16	21	1		2	10			10	1,100			10				
17	47			10	37			37	880			37				
18	733	3		141	501			501	1,440–2,100	±1,200		501				11
19	1,237	8	4	240		514	130	644	4,330	±2,560		27			487	
20	183	8	3	4	105			105	1,900–2,100			99			4	
	2,559	32	7	408	942	514	130	1,586								
21	64	6	5	5	54			54	1,200			47			7	
22	158	3		17	87		12	99	2,720–3,500			5			82	
23	188			6	29		1	30	1,600–3,500			10			19	
	410	9	5	28	170		13	183								
24	18	4		2			14	14	2,100–2,400	±1,300						
25								[6]								
26	5,213	109	53	484	2,079	522	185	2,786								

[6] Without other small fields, which include in Jaslo district (Magure Zone) approx. 130 wells, in Drohobycz district approx. 38 wells, and in Stanislawow district (Sloboda Rung., Kosmacz) approx. 64 wells.

In spite of this increase in the number of producing wells, production could not be maintained at the same level in the fields of Boryslaw and Bitkow (district of Stanislawow). The total oil production during the years 1930–1934 is shown in Table 5.

TABLE 5.—*Total Oil Production, Poland*
In cars (10,000 kg.)

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawow	Total
1934	9,953	9,141	30,426	3,268	52,788
1933	9,645	9,588	32,514	3,320	55,067
1932	9,582	9,043	33,029	4,014	55,668
1931	9,765	9,491	39,070	4,702	63,028
1930	8,535	8,561	44,334	4,847	66,277

Some time during 1930–31 a gradual improvement of exploitation by means of the "Mariette" method was introduced in the fields of Lipinki, Potok, Schodnica and Urycz. By the end of 1933, in four sections of the Schodnica field an increase of production was obtained, which

TABLE 1.—(*Continued*)

	Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1934					Character of Gas, Approx. Average during 1934	Producing Rock
	Initial	Average at End of		Gravity A.P.I. at 60°F.			Sulfur, Per Cent	Base[f]	B.t.u. per Cubic Foot	Name
		1933	1934	Maximum	Minimum	Weighted Average				
1				31	35	33	0.13–0.30	P	1.124	Cięzkow sands (I-II) and Cre.
2				37	41	38	0.12	A	1.124	Cięzkow sands
3				26	28	28	0.22	A	1.011	Krosno beds
4	1,420		II hor. 144 III hor. 800	36	41	38	0.10	A	1.011	Cięzkow (II) and Cre. (III)
5						37	0.09–0.15	A	1.011	Cięzkow (I-II) Czarnozecki (III)
6	497	128		38	51	45		A	1.011	Cięzkow (I-II)
7		71–142		28	34	33	0.09	A	1.124	Cięzkow (II)
8	1,400	710		34	36	36		P	955	Cięzkow (I) & gas (II)
9	490–710	71				40	0.15	A	1.067	Cięzkow (I-II) and III
10				32	37	32	0.13	A	1.124	Czarnorzecki
11	710	428	120			34	0.10	M	1.124	Ciezk. (I-III) Cre. (IV)
12				17	49	29		A	1.124	Cięzk. (I-III)
13				39	44	43	0.16	A		Krosno beds
14				32		35	0.29	P		Krosno beds low. and Menil. upp.
15				31	37	34		PM		Krosno beds low. and Menil. upp.
16				38	49	32		PA		Krosno beds low. and Menil. upp.
17				31	33	37		P		Sandst. Eocene & Tamna
18				29	39	34	0.17	A		Tamna
19				31	35	36	0.25	P	1.461	Horiz. I-VI (III-IV) Boryslaw)
20				36		34	0.29	A		Kliwa beds (1–3)
21					38	42		A		Hor. I-II
22				38	43	42	0.28–0.37	P	1.067	Hor. I-IV (Kliva beds)
23				37	43		0.13–0.48	PM		(Hor. O, II-IV (Kliva beds)
24										Tartonian beds
25										

amounted to 1322 cars[1] (a car is 10,000 kg.). A new company, the Polish Association of Petroleum Engineers, is actively at work in the Boryslaw area endeavoring to rationalize exploitation.[2]

The principal events in Poland during 1934 were the development of gas operations in the Daszawa-Gelsendorf gas fields (Stryj district, Sub-Carpathian Province) and in two fields of the Jaslo district. By the end of 1933 geophysical work undertaken by the "Pionier" company in all of the Daszawa territory confirmed the probability of a northwestern extension of the structure of the Daszawa gas field. These indications were utilized by two companies (Malopolska and Polmin), which have leased considerable areas in this district. In 1934 three prospecting wells proved that an area of not less than 200,000 acres is probably gas-bearing in Miocene formations in this district.

In the Jaslo district the well Roztoki No. 5, on the anticlinal fold of Jaszczew-Potok, yielded from a depth of 1024 meters in Eocene beds a flow of gas up to 800 cu. m. per minute (open flow). Well Roztoki No. 3, which from a depth of 1001 m. gave an initial gas production of

TABLE 1.—(*Continued*)

Line Number	Producing Rock			Net Thickness, Average Ft.	Structure^f	Number of Dry and or Near-dry Holes to End of 1934	Deepest Zone Tested to End of 1934	
	Age^g	Character^h	Porosity,^{i} Per Cent				Name	Depth of Hole Ft.
1	Eoc. Cret.	Sandstone	18.7-21.3-2.5	80	AM			
2	Eoc.			120	diap			
3	Olig.			150	A			
4	Eoc. Cret.		12.2	245	diap		Rozt. N5-Eoc. hor. (gas)	3,277
5	Eoc. Cret.			198	diap			
6	Eoc.			80	AF			
7	Eoc.			190	diap			
8	Eoc. Cret.			100	diap		Górki, Cret. hor. gas	3,898
9	Eoc. Cret.		19.6-18.4-20.5	200	diap	3		
10	Cret.			100	AM			
11	Eoc. Cret.			160	A			
12	Eoc.			132	A			
13	Olig.				AF			
14	Olig.			30- 40	diap			
15	Olig.			30- 40	diap			
16	Olig.			30	AF			
17	Eoc. Cret.			45	A			
18	Cret.			80-150	A			
19	Olig. Eoc. Cret.		10-15-17.4	IV = 30-120	AF	1	Orów overthrust a. Olig.	7,277
20	Olig.			30- 60	AF	3		
21	Eoc.			60- 80	A	2		
22	Olig.			15- 30	AF			
23	Olig. Cret.			15- 30	AF			
24	Mioc.		25	30- 40	A(D)	2	Rachín-Tortonian; Modrycz-Salt formation	4,560 5,613
25								

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[1] H. Gòrka: Les Résultats de la Méthode de Mariette dans les Mines de Schodnica et de Urycz. Service géologique carpathique I, 1933.

J. Czastka: Problèmes de l'Exploitation Rationelle des Couches pétrolifères dans le Bassin Occidental. Przemysl Naftowy, 1934.

[2] O. Wyszynski: La Corrélation des Horizons Pétrolifères dans les Grés de Boryslaw à Tustanowice-Est. Service géologique carpathique, *Bull.* 24, 1934.

120 cu. m. per minute, had already been completed in 1933. Another well at Gorki (Strachocina field), on the anticlinal fold of Turzepole, gave a flow of gas of 120 cu. m. per minute from a depth of 1218 m. in Cretaceous beds (open flow). The closed-in pressure in this well is approximately 92 atm. Each of the wells mentioned above increased the proven gas field area by at least 60 acres. All these wells belong to the state enterprise "Polmin," and the gas is being carried through the Jaslo-Krosno-Moscice gas line to the large state plant of nitrogen products near the city of Tarnow.

The extension of the area of the gas fields has not yet had any influence on the increase of gas and gasoline production. (See Tables 6 and 7.)

Table 6.—*Total Gas Production, Poland*

Thousands of Cubic Meters

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawow	Total
1934	111,200	303,500		43,300	458,000
1933	97,664	142,978	176,972	44,597	462,211
1932	86,347	115,811	186,764	48,008	436,030
1931	86,719	127,549	211,763	47,792	473,823
1930	75,432	120,034	242,612	48,428	486,506

Table 7.—*Gasoline Production, Poland*

Kilograms

Year	Jaslo	District Drohobycz	Stanislawow	Total
1934	4,382,000	33,123,303	2,961,817	40,467,120
1933	4,033,312	34,924,813	3,020,301	41,978,426
1932	2,521,915	33,257,716	3,053,045	38,832,676
1931	1,455,932	36,140,120	3,384,970	40,981,022
1930	197,240	34,903,905	3,392,505	38,493,650
Number of gasoline plants in 1934	7	16	4	27

The Boryslaw-Tustanowice-Mraznica fields are the main producers of gasoline, since they yield the largest amounts of casinghead gas.

The production of ozokerite is slightly decreasing, not because of exhaustion of the ozokerite deposits but because of unfavorable market conditions. In the autumn of 1933 the ozokerite mines were closed down and they remained practically idle in 1934, during which year the mines supplied demands by reducing their stocks, which on the first of January, 1934, amounted to 99,937 kg. Statistics for several years are given in Table 8.

TABLE 8.—*Ozokerite Production, Poland*
Kilograms

Year	Boryslaw	District Stanislawow Dzwiniacz-Starunia	Total
1934	76,988	21,327	98,315
1933	326,648	39,368	366,014
1932	308,815	279,887	588,702
1931	110,050	152,253	262,303
1930	681,255	220,401	901,656

Three wells of the Pionier company, one at Rachin (depth 1425 m.) and another at Modrycz (depth 1754 m.), both of which are in the Sub-Carpathian Province, and a third one at Orow (depth 2274 m.) in the Carpathian Province, were all abandoned in 1934. These wells once more confirmed that the existence of local structures alone is an insufficient feature for the discovery of oil.

On the basis of wider geological conceptions, it is possible to foresee not only that geological conditions similar to those that have been known for a long time in northwestern Germany may exist in the plains of western Poland, but that in northern Poland there may be underground conditions similar to those of the western slope of the Ural mountains, where oil occurrences were discovered recently in Permian and Carboniferous limestones. To prove this, it would be necessary to do preliminary geophysical investigation over the whole of this territory.

The backwardness of the domestic market of a country that has a population of 32,000,000 and covers an area of 388,000 sq. km. is the only obstacle at present to improvement of the oil industry in Poland and stifles any initiative in the way of research work for the discovery of new oil fields.

Petroleum Development in Rumania in 1934*

(New York Meeting, February, 1935)

Both drilling and production in Rumania showed increases in 1934 over 1933. The drilling totaled 1,138,000 ft. and production 63,500,000 bbl., being increases of 50 and 15 per cent, respectively. During the year production gradually increased from 155,000 bbl. per day in January to 180,000 bbl. in September, and then declined slightly to the end of the year. The increases were largely due to competitive drilling in the Gura Ocnitei field (including west extension to Viforata). Wells completed during the year totaled 238, of which 215 were oil producers.

Table 1.—*Summary of Petroleum Production in Important Fields of Rumania during* 1934

Field	Production		Drilling		Wells Completed	Average Initial Production of Wells, Bbl.
	Total in 1934, Bbl.	Increase or Decrease	Footage Drilled	Increase or Decrease		
Moreni-Gura etc.[a]	41,879,000	+3,185,000	750,000	+249,000	171	850
Boldesti	10,793,700	+3,561,900	190,000	+ 74,000	23	1,700
Baicoi-Tintea	783,100	+ 6,300	4,000	+ 2,000	2	200
Ceptura	3,153,900	− 169,400	4,000	− 16,000	1	450
Aricesti	2,726,500	+1,531,400	84,000	+ 8,000	14	1,650
Bustenari-Runcu, etc	2,592,500	− 178,900	44,000	+ 26,000	17	425
Others	1,571,300	+ 161,100	62,000	+ 28,000	10	400
	63,501,000	+8,097,400			238	925

[a] Piscuri-Moreni-Gura Ocnitei-Ochiuri, etc., considered as one field.

The outstanding development of the year was the discovery by Steaua Romana of what appears to be a major field at Bucsani. Other important discoveries were a three-mile west extension of the Gura Ocnitei fault to Viforata and a five-mile east extension of the Moreni field to Calinesti. Strictly speaking, the latter cannot as yet be called an extension. Oil sands have been corded in the Meotic, and in all probability production will be established in 1935. The Calinesti discovery greatly restricts the unproved area between Moreni and Baicoi, and the probabilities of

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* Paper secured through W. P. Haynes, Member A.I.M.E., London, England.

production eventually being found all the way between Tintea and West Gura Ocnitei are now considered very good. This area, therefore, may prove to be one field, 23 miles long, which to date has produced 378,000,000 bbl. Of this amount 68 per cent has been obtained from the Dacic and 32 per cent from the Meotic. The grand total Rumanian production to date is 620,000,000 bbl., of which 61 per cent is from the Tintea-Moreni-Gura Ocnitei area.

The Aricesti field, which during 1933 was considered a major discovery, has proved to be of small importance. The oil-bearing zone has been found very narrow and the indications are that the field will be of very limited extent.

The Gura Ocnitei field, in which 49 per cent of the total drilling was done in 1934, is rapidly becoming drilled up, and this area is expected to show a drop in both production and development beginning with 1935.

A revival of interest was shown in the northeast section of the Runcu field, where fair producers were obtained at shallow depths.

Two wildcat wells drilled on the Valea Calugareasca anticline showed the south flank to be dipping very steeply. One well was stopped in vertical Dacic beds at 4925 ft. and the second, which reached 11,100 ft., found salt water in the Meotic. A third test is to be drilled to test the north flank.

A wildcat drilled at Dragomiresti, 5 miles west of the present limit of the West Gura Ocnitei field, found the Meotic reduced to a thickness of only 260 ft. This is in line with the tendency for the Meotic to thin gradually westward from the Buzau Valley, where it is 2000 ft. thick.

TABLE 1*a*.—*Oil and Gas Production in Rumania through* 1933[1]

Line Number	Field, *District*	Age, Years to End of 1933	Area Proved, Acres		
			Oil	Gas	Total
1	Boldesti, *Prahova*	10	2,600		2,600
2	Ceptura, *Prahova*	15	2,100		2,100
3	Ochiuri, *Dambovita*	20	1,240		1,240
4	Piscuri-Moreni-Gura Ocuitei-Razvad, *Prahova and Dambovita*	35	5,300		5,300
5	Aricesti, *Prahova*	13	1,400		1,400
6	Baicoi-Tintea, *Prahova*	40 ±	1,100		1,100
7	Copaceni, *Prahova*	29	120		120
8	Pacureti, *Prahova*	31	150		150
9	Runcu-Chiciura-Bordeui, *Prahova*	23	4,200		4,200
10	Bustenari, *Prahova*	100 ±	2,100		2,100
11	Campina, *Prahova*	50	790		790
12	Arbanasi, *Buzau*	28	400		400
13	Tetcauz, *Bacau*	30	150		150
14	Moinesti, *Bacau*	30	170		170
15	Solontz-Stanesti, *Bacau*	30			
16	Zenies-Taslau, *Bacau*	30	110		110
17	Moivesti, *Transilvania*				
18	Saros, *Transilvania*	19			19
19	Copsa Mica, *Transilvania*				
20	Sarmasel, *Transilvania*			385	385
21	Bazna, *Transilvania*				

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[1] The figures in this table were compiled by Messrs. Grigorescu, Toustiuc and Ionescu but were received too late to print in the 1934 volume. They cover Rumanian production up to the year 1934 but do not include that year.

Some oil traces were found in the well, but only thin sands occurred, resulting in a failure. Three wells are now drilling between this location and the West Gura Ocnitei field.

The state asked for offers on a footage basis for the drilling of a deep test for oil in a shallow gas field in Transilvania.

In other fields development was normal. A summary of production in important fields during 1934 is given in Table 1. (Table 1*a* gives figures for the previous years.)

The Petroleum Association has been trying to bring about a reduction in the high taxes and transportation charges which have placed the Rumanian producer at a great disadvantage as compared with producers in other countries. Normal paraffinous 38° A.P.I. oil varied in price from 32 to 40¢ per barrel. No progress has been made on the construction of a pipe line to Constantza for gasoline. The state railways oppose the construction of this line because of the resultant loss in investments and income. A project is under consideration for building a pipe line to Bucharest to furnish that city with natural gas. The restrictions on transfers of money in many European countries, including Rumania, have been a hindrance to the marketing section.

Considerable uneasiness is felt in Rumania over the competition

TABLE 1*a*.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Number of Oil and/or Gas Wells							
	To End of 1933	During 1932	During 1933	Daily Average during June, 1934	Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during June 1934	Completed to End of 1933	During 1933		At End of 1933				
									Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	21,788,160	8,219,985	7,231,800		8,400		670	57	15	2					46
2	20,542,330	2,880,490	3,323,250	8,900	9,780			178	5						60
3	30,243,500	2,276,953	1,935,047	5,375	24,790			243	1			37			37
4	298,081,124	35,658,232	36,615,075	113,426	56,200			1,800	117			583		1	584
5	1,196,150	1,025	1,195,125	59,500	854			29	12	2		17[3]			17[3]
6	31,617,731	908,265	768,507	2,436	28,800			560	1			55			55
7	744,600	72,060	165,100	430	6,200			10	4			5			5
8	237,667			1,578				3							
9	46,311,350	3,388,200	2,782,100	6,672	11,000			850	9			257			257
10	48,636,700			963	23,180			763				246			246
11	31,485,179	295,185	253,807	730	39,810		11	277				66			66
12	16,452,040	404,490	377,735	915	4,100			110							
13	662,882			57				30				79			19
14	1,713,567	58,540		275	10,280							14			14
15	3,119,593			322								86			86
16	3,031,383			387								29			29
17															
18								14[2]							
19								5[2]							
20								26[2]							
21								9[2]							

[b] Footnotes to column heads and explanation of symbols are on page 249.

[2] Gas wells.

[3] As of July, 1934.

TABLE 1*a*.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1933			Pressure, Lb. per Sq. In.	Character of Oil Approx. Average during 1933			
			Number of Wells				Gravity A.P.I. at 60° F.			
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Initial	Maximum	Minimum	Weighted Average	Base[f]
1	8,000	4,000					35.5°		36.9°	P
2	5,000	1,500							34.9°	P
3	Dacic-Meotic 1,200–4,000	1,100–3,700	7	30		2,000			34.9°	P, A
4	Dacic-Meotic 2,000–5,000	1,400–4,500	50	433	100	3,000	34.9°	21.4°	33°	A, P
5	6,000	5,500	17			2,000				P
6	2,000	1,000	5	50			45.3°	25.7°	40°	A, P
7	1,500	100		5			Light 41°			P
8	3,000					700	45.3°	21.4°	38.9°	A, P
9	2,500	700		257		1,000			38.9°	P
10	Meotic 300 Oli. 500			246			45.3°	41°		P
11	750	200		66					41°	P
12	1,000	200							37.9°	P
13	1,000	200		19					43.2°	
14	1,000	200		14			45.3°		43.2°	
15	1,000	200		86					43.2°	
16	1,000	200		29					43.2°	
17	330									
18	1,100	500								
19	2,000	600								
20	1,800	600								
21	1,000	500								

Line Number	Producing Rock					Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933		Reference to Text[k]
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.			Name	Depth of Hole, Ft.	
1	Upper and Lower Meotic	Pli	S	10–15	771	Surface A		Lower Meotic	8,202	
2	Upper and Lower Meotic	Pli	S		850	Surface A	38	Sarmatic	3,855	
3	Dacic and Meotic	Pli	S	15–20		Salt A	37	Miocene		
4	Dacic (Soft sand) Meotic (Soft & Hard Sd)	Pli	S	10–20		Salt A	198	Miocene	6,500	Water
5	Meotic	Pli	S	15–20		Salt A	26	Miocene	7,400	
6	Dacic and Meotic	Pli	S	10–25	500	Salt A	97	Meotic		
7	Meotic	Pli	S	10–15		Thrust Fault		Meotic	2,260	
8	Dacic, Pontic, Meotic (Prospect)	Pli	S	10–15		Open Ant.	10	Meotic	3,000	
9	Meotic	Pli	S	10–25		Ant. Terrace	92	Miocene		
10	Meotic and Oligocene	Pli and Olig	S	7–25		Thrust Fault		Oligocene		
11	Meotic	Pli	S, SH	10–20		Mono. Thrust Fault		Miocene		
12	Meotic	Pli	S	10–15	800	A		Miocene	2,800	
13	Miocene	Mio	S, SH			A[4]		Miocene	3,250	Dry hole
14	Pliocene Oligocene	Pli Olig	S, SH	15 7–12		[5]			3,500	
15	Oligocene	Olig	S, SH	7–12		[6]		Miocene	3,050	
16	Oligocene		S, SH	7–12		[5]				
17	Sarmatic	Mio				D				
18	Sarmatic	Mio				D				
19	Sarmatic	Mio				D		Miocene	2,510	
20	Sarmatic					D		Miocene	2,950	
21	Sarmatic					D				

[4] Probably faulted. [5] Overthrust fault. [6] Burning since July 11, 1933.

from Iraq oil. This potential competition is being used as an argument in favor of constructing a pipe line to Constantza. Of Rumanian exports, 85 per cent pass through Constantza, most of which will be affected by this competition.

Electrical coring was done by the Schlumberger company in practically all wells drilled. This company has recently introduced an electrical apparatus for making oriented surveys, but as yet this has not been used extensively.

Several attempts were made with directional drilling, but this is still in an experimental stage in Rumania, and repressuring is practically unknown. Its adoption is handicapped by the multiplicity of ownership in the various fields.

Venezuela

(New York Meeting, February, 1935)

Increased world consumption of crude and products coupled with the trend toward supplying this demand from the nearest and most economical source of supply had the economic effect of broadening the demand for Venezuelan crude. As a result of this, Venezuela produced more in 1934 than in 1929, the previous peak year. During 1934 Venezuelan output is estimated at a total of 139,382,000 bbl., a daily average of 381,868 bbl., against 120,442,000 bbl. in 1933, a daily average of 329,978 bbl. This is an increase of 51,890 bbl. per day.

It is interesting to note from the comparison of production for the past 10 years (Table 1) that in spite of the fact that Venezuela produced more in 1934 than in 1929 its share of world production is slightly less than in 1929 and 1930.

Table 1.—*Production of Oil in Venezuela*
(Barrels of 42 U.S. Gallons)

Year	Total	Daily Average	Per Cent of World Production
1925	20,409,137	55,915	1.91
1926	36,929,987	101,179	3.36
1927	63,176,760	173,088	5.00
1928	105,761,531	288,966	7.96
1929	137,535,230	376,810	9.22
1930	136,987,662	375,309	9.63
1931	118,878,971	325,696	8.63
1932	118,110,000	322,705	9.03
1933	120,442,246	329,978	8.33
1934	139,382,000[a]	381,868	9.15

[a] Partly estimated.

During the latter part of 1934 Venezuela produced its first billionth barrel of crude. Only three other crude-producing countries of the world have attained this distinction; namely, United States, Russia and Mexico. Venezuela still ranks third in the producing countries of the world, being surpassed by the United States and Russia.

Exports of crude and products from Venezuela for 1934 are estimated at 133,400,000 bbl. This is an increase of 16,107,000 bbl., or 13.73 per cent as compared with 1933.

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TABLE 2.—*Summary of Production in Venezuela during 1934*

	Total Crude Production			Status of Wells Nov. 30, 1934										Wells Completed 11 Months 1934	Age of Field, Years
				Producers						Nonproducers			Total Drilled		
	1933	1934	Daily Average Nov., 1934	Flowing	Pumping	Air-gas Lift	Total Producing	Closed In	Total	Inactive	Workovers	Abandoned			
Ambrosio	1,634,374	23,057,211	5,608	5	51	0	56	20	76	33	1	15	125	0	9
La Rosa	21,650,132		41,420	72	189	69	330	200	530	264	3	50	847	16	12
Punta Benitez	1,908,581		9,146	27			27	11	38	18	0	5	61	12	9
Tia Juana								7	7	1	0	1	9	0	7
Lagunillas	58,683,492	72,619,348	221,758	220	155	113	488	30	518	214	9	11	752	103	9
Bachaquero								3	3	1	0	0	4	0	5
Total lake fields	83,876,579	95,676,559	277,932	324	395	182	901	271	1,172	531	13	82	1,798	131	
Mene Grande	13,048,134	15,235,057	42,623	32	0	94	126	35	161	73	1	14	249	9	20
La Paz	281,459	241,367	599	3	1	1	5	0	5	22	0	4	31	0	10
Concepcion	2,154,674	1,742,679	4,456	4	64	4	72	0	72	29	0	1	102	0	10
Rio Tarra	3,349,578	4,414,621	13,327	9	12		21	7	28	40	0	12	80	3	13
Los Manueles	4,217,460	2,038,387	4,099	8	0	0	8	5	13	0	0	1	14	1	5
El Mene and Media	1,704,465	955,230	2,466	4	44	46	94	0	94	88	0	134	316	7	12
Hombre Pintado	14,680	16,694	32	1	0	0	1	4	5	0	0	0	5	0	7
Cumarebo	4,931,352	3,860,661	9,837	35	0	0	35	15	50	5	0	13	68	25	3
El Mene de Acosta	99,270	46,694	106	0	13	0	13	0	13	10	0	55	78	0	6
Quiriquire	6,756,730	13,721,766	40,688	50	14	0	64	13	77	9	0	9	95	33	8
Pedernales and Orocual	7,841	35,549	99	2	1	0	3	1	4	0	0	7	11	5	
Others				0	0	0	0	37	37	2	0	25	64	2	
Total	120,442,222	137,985,264	396,264	472	544	327	1,343	388	1,731	809	14	357	2,911	216	

Field Developments

No new fields were discovered during 1934. Several dry holes were completed in the Falcon area and developments in the Pedernales area proved disappointing during the year. Additional drilling at Oracual also proved disappointing.

In the State of Anzoategui, developments were shut down during the rainy season of 1934 and in the latter part of the year drilling crews were again moved into this area to continue drilling.

In the developed areas the Bolivar Coastal fields, which include Ambrosio, La Rosa, Punta Benitez and Lagunillas, continued to be the principal producers. As shown on Table 2, this area produced 95,676,559 bbl. during 1934, or about 69 per cent of the total for the country. One hundred and thirty-one wells were completed in this group of fields, making a total of 1731 to date. During the year about 100 wells were transferred from the gas-lift stage to the pumping stage. On Nov. 30, 1934 there were 395 wells pumping, 189 of which were in the La Rosa field and 155 in the Lagunillas field. As a result of drilling, the proven area of the Lagunillas was extended slightly lakeward.

The Mene Grande field showed a slight increase during the year and outside of La Rosa and Lagunillas, in the Bolivar Coastal fields, was the third largest producing area in Venezuela. Its total production amounted to 15,235,057 bbl. In the first 11 months of the year nine wells were completed. At the end of the year five strings of tools were active in this area. A number of wells were placed on the gas-lift during 1934.

Drilling operations in the La Paz and Concepcion fields were shut down during the entire year and production in both of these fields showed a slight falling off from the previous year.

In the Rio Tarra field in the District of Colon three wells were completed in the first 11 months of the year and production showed an increase of a little over one million barrels for the entire year. Los Manueles, another field in the District of Colon, showed a decrease of about two million barrels with only one well completed during the year. Active drilling operations in the District of Colon were practically suspended at the end of 1934.

In the El Mene and Media area seven wells were completed. Production in this area, which is practically all drilled up, continued to decline and for the year 1934 showed a falling off of approximately 42 per cent when compared with 1933.

In spite of the fact that 25 wells were completed in the first 11 months of 1934, production in the Cumarebo area showed a decrease of approximately 22 per cent.

In the Quiriquire field drilling operations throughout the year were in the area previously proven. Thirty-three wells were completed during the first 11 months of 1934. Production for the year totaled 13,721,766 barrels.

Russian Oil Industry in 1934

By Basil B. Zavoico*

After showing continued and very satisfactory progress until the close of 1931, the oil industry of the Soviet Union experienced very great difficulties, and since 1932 has not only failed to complete its assigned quotas but has fallen farther and farther behind them, and in fact during 1932 and 1933 Russian production has been below production in 1931. In 1934 the total crude oil production of 169,200,000 bbl. exceeded that of the former peak year, 1931, when 156,100,000 bbl. were produced. The production during 1934 amounted to 78.65 per cent of the plan. The failure to complete the plan has been due to the inability of the oil trusts to develop new fields; the fields that have been producing since 1917 still account for between 75 to 80 per cent of total production. The failure of the Soviet Government to develop new fields has been due to unsatisfactory organization of the geological work, to the extremely slow drilling of wells and their exploitation, and to the very much delayed development of the few areas that have been discovered.

The official overestimation of the proven reserves of the country has undoubtedly been an important factor in giving the Soviet industry too much confidence when actually such reserves have been small. The official Soviet estimate of proven reserves of Russia is now placed at 21,000,000,000, bbl., while in fact such reserves, if estimated on a conservative basis, do not exceed 4,200,000,000 bbl., as will be shown later in this review.

The refinery branch of the industry also showed unsatisfactory results with a recovery of gasoline, both straight-run and cracked, of only some 16 per cent of the total runs to stills. In fact, the showing of the refineries has been so unsatisfactory that the exports of gasoline have been greatly curtailed from 1933 to 1934, dropping to 10,000,000 bbl. in 1934 from 12,230,000 bbl. in 1933. With the indicated increase in domestic demand, together with but slightly increased refining capacity, the volume of available gasoline for export probably will be reduced to about 6,000,000 bbl. during 1935.

The geographic distribution of constructed refineries has been unsatisfactory and the crude oils from Baku had to be transported by tankers

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and pipe lines to Grozny refineries, because production from Grozny fields has rapidly declined during the past several years.

PRODUCTION

During 1934 the crude oil production from all Russian oil fields amounted to 169,200,000 bbl., or 464,000 bbl. per day, as compared with 149,900,000 bbl., 410,000 bbl. per day, in 1933, indicating an increase of 12.90 per cent. The plan was thus fulfilled only to the extent of 78.65 per cent, because the fields were assigned to produce 214,900,000 bbl., 588,000 bbl. per day, during 1934.

Apsheron Peninsula.—The oil fields of the Apsheron Peninsula (Baku) accounted for 78.50 per cent of the total crude oil production of the Soviet Union in 1934, producing in that year 133,000,000 bbl., 364,000 bbl. per day. The Baku oil fields in 1933 and 1934 showed remarkable gains in production increasing from 88,370,000 bbl. in 1932, in which year Baku contributed only 59 per cent of the total Russian production. The increased production in the Baku oil fields has been due to the great decline in production in the Grozny fields, which practically forced the Soviet oil industry to develop the known fields of the Apsheron Peninsula at the utmost speed. An important factor in the increased production of the Baku fields in the last two years has been the putting into more rapid exploitation of the new fields, the Lok-Batan, Kara-Chukhur and Kala; these three fields accounting for some 20 per cent of the total Baku output in 1934. It is rather doubtful that the Baku oil fields can continue to increase their production at the rate the domestic industries will require, unless new large fields are discovered and actively developed. Probably the increased rate of production of the older fields of Baku in the last year will accelerate the recovery and may cause in the future a more rapid decline in production than would have been the case if the production from these older fields was maintained at a steady rate. The increased production in the older areas has been made possible in part by drilling to the deeper sands, though at this time most of the Pliocene "oil measures" have been tested in the older fields of the Apsheron Peninsula. The Baku district undoubtedly has a very large oil reserve in undiscovered fields. The area of this district includes the Saliani Steppes, due south from Baku, and some territory to the north of the Apsheron Peninsula, more particularly the Berekei district.

Grozny.—Very unsatisfactory results have been shown by the Grozny fields, which after reaching the peak of 56,500,000 bbl. in 1931, in which year Grozny produced 36.20 per cent of the national output, declined to 23,600,000 bbl. in 1934, accounting for 13.96 per cent of the country's production. The marked drop in production of the Grozny fields has been due entirely to the overexploitation of the two old fields in the district, and the failure of the Grozneft trust to bring into production any new fields. The two old fields of the Grozny district will continue their sharp decline in production, and, unless new fields are discovered and rapidly developed, the Grozny area promises to lose all of its previous importance. The unfavorable development is quite unexplainable because in the first place the sharp decline in production in the two old fields could have been foreseen easily; and secondly, because the Grozny district, in the foothills of the Caucasian Range, undoubtedly is one of the richest petroliferous provinces of the world and if Grozneft, instead of drilling unnecessary wells in the old fields, had concentrated on exploration work, new major fields undoubtedly would have been discovered by this time. Two fields of some importance are being developed by Grozneft at this time, the Molgabek and Benoi, but the delay in the construction of roads, which entails very slow transportation of equipment and supplies, makes active development nearly impossible. It is reported that the transportation departments of the Soviet Government refuse to construct extensive highways until large reserves are proved in the new fields and, of course, these reserves of crude oil cannot be developed until satisfactory highways are constructed.

Kuban-Maikop.—The third major district in Soviet Russia today is the Kuban-Maikop, which is but a short distance from the Black Sea, and which is an extremely promising area for discovery of several major oil fields. In 1934 the Maikop fields produced 6,570,000 bbl., 18,000 bbl. per day, or 3.88 per cent of the national output. While the production of the Maikop district has shown a steady increase since 1928, the increase has not been commensurate with the potentialities of the area, with its proximity to the Black Sea and with its easy accessibility, not requiring extensive highway construction.

Emba.—The production from the Emba oil fields continued in the last several years at a very slow rate, producing in 1934 but 4600 bbl. per day or but 0.99 per cent of the country's output. Two new fields in the Emba district were to be brought into production in 1934, the Koschagil and Iskin, with a reported potential production of 10,000 bbl. per day. Some 300 salt domes were reported discovered in the Emba district in the last few years, but the value of the large number of salt domes must necessarily be discounted since production from the Emba continues in fact unusually small. The Soviet Government is planning several major projects in the Emba district, including supply of water, highways and power plants, but the development of this far away district while strategically located prospective areas, easily accessible to the existing facilities of Baku and Grozny, lie half dormant is at best a questionable policy.

Other Fields.—A few promising fields are being brought into production north of the Emba district in the Sterlitamak area, where the Ishimbaevo field has 15 completed oil wells with a reported production of (potential)

7000 bbl. per day. This crude oil, however, has a very high sulfur content, from 2 to 5 per cent, and will require construction of special refineries to treat it. No new discoveries of major importance have been made recently in the Soviet Union, with the possible exception of the Turkestan, where a few very large gushers have been completed in Neftedag; this area however, is very erratic. On the other hand, the oil prospecting in the Chusovo area of Perm Province, where some 60 wells have been drilled, and of the Baikal district in Siberia, has been entirely discontinued because no results have been shown.

Summary.—To sum up the situation in the oil fields of Soviet Russia today, it may be easily seen that the discovery and the effective development of new fields is the matter of major importance to the Soviet Union, not only in order to maintain the exports but even to supply the rapidly increasing domestic demand.

RESERVES

The official estimate of proven reserves of crude oil in Russia probably has been responsible, at least in part, for the impasse in which the Soviet oil industry finds itself today, because the overoptimistic statements were responsible for half-hearted wildcatting. The following estimates are the official Soviet figures while the corresponding estimates of the author are based on the American practice, and are, if anything, excessive. The Baku oil fields have an estimated reserve of 9,275,000,000 bbl., as given by the Soviet Government, while its actual reserve probably does not exceed 3,500,000,000 bbl. of which 2,000,000,000 bbl. are in the old fields, and 1,500,000,000 bbl. are in the new fields. The official Soviet estimate for Emba district is 4,480,000,000 bbl. for an area that currently produces only 4000 bbl. per day, and an estimate of 100,000,000 bbl. is probably more correct. The Maikop fields are estimated by the Soviet Government to contain a reserve of 575,000,000 bbl., and while the fields are very promising an estimate of 250,000,000 bbl. probably would be excessive. The new field of Sterlitamak is assigned by the Government 420,000,000 bbl. but again 100,000,000 bbl. is probably more nearly correct. The Grozny oil fields are estimated by Grozneft to contain about 1,000,000,000 bbl. but considering rapidly declining production it is doubtful whether the proven reserves of that district exceed 150,000,000 bbl. The Soviet Government estimates the reserves of Turkestan at 1,680,000,000 bbl. but the present fields certainly cannot be counted upon to produce more than 100,000,000 barrels.

Thus a liberal estimate of the proven reserves of Russia today is about 4,200,000,000 bbl. as compared with the official figures of 21,000,000,000 bbl. The psychological effect of a proven reserve estimated at 21,000,000,000 bbl. on wildcatting is self-evident and probably was, as already indicated, responsible for the confidence of the central government oil bureaus in their ability to increase at will crude oil production in the past and in the near future to 300,000,000 bbl. a year, which, in fact, cannot be obtained without new discoveries and reorganization of the production department.

DRILLING

The drilling technique in Soviet Russia continues to present one of the most difficult problems. The drilling time is unusually slow, four to five months being required to complete wells under normal conditions, to a depth of about 3500 ft., while for some wells as long as one year is required to bring them into production. The record in Soviet Russia to date is a well that was completed in 39 days to a depth of 3660 ft., which compares with the average time of 10 days to the same depth in East Texas. In 1934 a total of 4,123,000 ft. was drilled in all fields of Russia, fulfilling the plan to the extent of 83.3 per cent. This figure compares with 2,788,000 ft. drilled in 1933. In all, 1100 rotary rigs are in operation in the U.S.S.R. today, of which 270 are heavy duty. The average depth of new oil wells is 3200 ft. in Baku and 3600 ft. in Grozny. During the year, 1188 wells were completed in Russia, of which 947 were producers, and in addition some 500 old wells were repaired and brought back into production.

Most illuminating conclusions can be made in comparing producing and drilling data for 1933 and 1934. Thus in Baku district a 47.8 per cent increase in drilled footage resulted in a 23.9 per cent increase in production; in Grozny a 77.8 per cent increase in drilled footage resulted in a 30.8 per cent decrease in production; in Maikop a 46.3 per cent increase in drilled footage resulted in a 58.6 per cent increase in production; and in Emba a 28.6 per cent increase in drilled footage resulted in a 21.8 per cent increase in production.

The 1935 plan for drilling provides for 5,214,000 ft., but merely increasing the drilling in old fields will not solve the problem; the drilling must be done in new fields.

The turbine drilling system of Kapelushnikoff was entirely abandoned in the last few years as being uneconomical as compared with the standard rotary practice.

REFINING

In 1934 a total of 145,141,000 bbl. of crude oil was run to stills in all Russia as compared with the plan of 161,000,000 bbl., which resulted in a recovery of 23,700,000 bbl. of gasoline and 34,800,000 bbl. of kerosene. Gasoline production was about evenly divided between straight-run and cracked. During the previous year, 131,591,000 bbl. was run to stills, recovering 22,300,000 bbl. of gasoline and 30,000,000 bbl. of kerosene.

The present refining capacity of Soviet Russia is 163,450,000 bbl. per year while the current capacity of cracking stills is 29,600,000 barrels.

The Soviet Government plans to erect in the immediate future some 20 new cracking stills, adding 16,000,000 bbl. per year cracking capacity, and also plans construction of new topping plants with a capacity of 30,000,000 bbl. per year. This construction will bring the capacity of Soviet Russia in 1937 to 192,000,000 bbl. while the capacity of cracking stills in that year will reach 46,700,000 bbl.

The Soviet Government estimates that in 1937 it will require for domestic use 100,000,000 bbl. of gasoline and 60,000,000 bbl. of kerosene, and apparently this figure will not be attained in 1937, because even if total gasoline recovery should increase from the present 16 per cent to 25 per cent the planned capacity of refineries will produce in 1937 but 48,000,000 bbl. of gasoline. The delay in construction of refineries in the last three years has been due undoubtedly to the indecision of the government as to where such refineries should be constructed, because in the past the refineries and cracking plants have been built, as described below, in strategically poor localities. In the years when the Soviet oil industry was counting very much on the production from the Grozny oil fields, it built up a refining capacity of some 85,000,000 bbl. per year in Grozny and Touapse, but in that district production in 1934 was actually only 30,000,000 bbl., thus necessitating the shipment of Baku crude oil over the Caspian Sea to Petrovsk (Makhach-Kala) and then by pipe line to Grozny refineries. In the previous year, 5,130,000 bbl. of Baku crude oil was shipped to Grozny refineries while in 1934 these shipments increased to 20,700,000 bbl. While the expense of shipping the crude by sea and pipe line is in itself an economic waste, far more important is the fact that it reduced in 1934 by 10,000,000 bbl. the shipping facilities from Baku to Astrakhan and to the interior of Russia. The reduction in shipping capacity is considered at only 10,000,000 bbl. because Petrorvk remains open for shipping much later in the year than Astrakhan, though continued shipments necessarily reduce the time for overhauling the tankers, which previously was done during the winter months.

Domestic Demand and Exports

Russia consumed 108,000,000 bbl. of petroleum products in 1934 while it exported 28,000,000 bbl., thus reducing the percentage of exports in the last two years from 30,000,000 to 20,000,000 bbl., and a further reduction in exports, both in volume and in percentage of total Russian production, is inevitable. Thus in 1935 the Soviet oil administration anticipates using in the country 130,000,000 bbl. and plans to export 43,000,000 bbl., planning to produce in that year some 220,000,000 bbl. of crude oil, but it is extremely doubtful whether the production of crude oil will exceed 175,000,000, bbl., in which event only 150,000,000 bbl. of petroleum products will be available. This would mean that the Government will have available for export only some 20,000,000 bbl. of petroleum products; especially the export of gasoline will have to be reduced because with the current refining capacity only some 25,600,000 bbl. of gasoline will be produced in 1935 while the domestic demand in that year is estimated at about 19,200,000 bbl., leaving for export only 6,400,000 bbl. as compared with 10,000,000 bbl. exported in 1934 and 12,230,000 bbl. exported in 1933. Comparable reductions in exports of kerosene will also be necessary. The domestic demand for gasoline has been estimated in this report on the basis of automobiles, tractors, and airplanes in use in 1934 and in 1935. On the first of January, 1935, there were in use in Russia 180,000 automobiles, 311,000 tractors, 35,200 combines, and about 3,500 airplanes. These figures are to be compared with the estimates that on the first of January, 1936, there will be in Russia 272,000 automobiles, 408,000 tractors, 50,200 combines, and some 5,000 airplanes, this increase in motorized transportation and in traction power being approximately 40 per cent.

TABLE 1.—*Crude Oil Production in U.S.S.R., Millions of Barrels*

Year	Total Production			Production by Major Fields							
				Baku		Grozny		Maikop		Emba	
	Actual	Plan	Percentage of Fulfillment	Production	Percentage of Total	Production	Percentage of Total	Production	Percentage of Total	Production	Percentage of Total
1916	72.80			55.81	76.55	12.73	17.48	0.40		1.82	
1920–1921	26.60										
1921–1922	32.90										
1922–1923	37.17			25.30	68.05	10.90	29.32			0.97	2.61
1923–1924	44.40			31.30	70.45	11.80	26.55	0.25	0.56	0.90	2.03
1924–1925	51.12			33.90	66.15	15.14	29.55	0.40	0.78	1.43	2.79
1925–1926	59.89			39.98	66.70	18.00	30.00	0.34	0.57	1.57	2.62
1926–1927	73.98			49.00	66.20	22.79	30.80	0.36	0.49	1.83	2.47
1927–1928	82.60			54.15	65.50	25.90	31.30	0.41	0.50	1.82	2.20
1928–1929	96.80			62.10	64.20	30.60	31.60	1.80	1.86	1.86	1.93
1929–1930	124.00			73.60	59.40	44.11	35.60	3.00	2.42	2.46	1.98
1931	156.10			92.80	59.45	56.50	36.20	3.30	2.11	2.00	1.28
1932	149.72			88.37	59.00	53.90	35.95	3.55	2.37	1.70	1.14
1933	149.90	170.80	87.60	107.30	71.51	34.10	22.75	4.14	2.76	1.38	0.92
Daily Prod.	0.410	0.467		0.294		0.093		0.014		0.0038	
1934	169.20	214.90	78.65	133.00	78.50	23.60	13.96	6.57	3.88	1.68	0.99
Daily Prod.	0.464	0.588		0.364		0.065		0.018		0.0046	
	Estimates										
1935		232.40[a]									
Actual first quarter 1935 daily average				0.364	80.00	0.049	12.20	0.021	4.70	0.0040	
1936		260.00									
1937		315.00									

[a] Including gas production; net crude oil quota 220,800,000 barrels.

CONCLUSIONS

The year 1935 is the critical year for the Soviet oil industry. The rapid increase in the demand for motor fuel and other petroleum products by the domestic industries promises to outstrip any possible increase in crude oil production and refining unless the oil industry of the Soviet Union is completely and entirely reorganized. As reviewed in this article, the more important problems that face the oil industry in Russia and the problems that must be solved immediately by competent authorities and engineers are:

1. Satisfactory geological research.
2. Active wildcatting with better service of supplies, so that the wildcat wells will not be unduly delayed.
3. Rapid and active development of newly discovered fields, which will necessitate rapid construction of highways into the fields.
4. Increase in drilling efficiency; even if not approaching the American practice, at least allowing completion of wells in average time 60 days to 3500 feet.
5. Efficient service of supplies, which includes all phases of the oil industry, geological, drilling, production and refining.
6. Construction of modern refineries and provisions for such refineries to be kept up to date continuously, rather than their construction and operation in unchanged form while the refining practice advances each year.
7. The building of strategically located refineries, so that the change in the source of supply of crude oil will not affect the refining industry.

Chapter VI. Refining

Developments in Petroleum Refining Engineering in 1934

By Walter Miller,* Member A.I.M.E.

The broad picture of petroleum refining engineering during 1934 continued to show a tendency in the direction of highly specialized processing improvements, particularly in manufacture of lubricating oil.

The slowing up of the trend toward higher octane products in non-premium gasoline noticed in 1933 was definitely established as a fact by 1934 development, with just a slight indication of recession. No outstanding engineering achievements can be credited to 1934 in refinery cracking, unless the completion and successful operation of the 30,000-bbl. crude capacity combination cracking and skimming unit at Texas City, Texas, and a 20,000-bbl. similar unit in the East can be listed as such. Development and improvement was largely a continuation of previous lines of endeavor. Such trend as there is shows a continuation in the direction of very large integrated skimming and cracking units.

A lessening of the cost of ethyl lead, coupled with the reaching of the octane number "ceiling," kept the subject of "reforming" low-octane gasoline into high-octane products pretty well in the background. Considerable interest, however, was shown during the year in cracking and polymerizing of refinery gases into high-octane motor fuel. The commercial development and application of this activity was greater in 1934 than during any previous year. Fair yields of gasoline of satisfactory stability and high antiknock value were reported, ranging from 2 to 8 gal. per 1000 cu. ft. of fixed refinery gas, yields varying with both the nature of refinery gas treated and processing methods. Assuming economic feasibility, regarding which there is still difference of opinion, gas polymerization offers the industry a possible outlet for its gases more in keeping with its basic chemical composition and value.

The increased interest of railroads and heavy-duty truck and tractor manufacturers served to focus more attention on diesel fuels. The publicity given the Union Pacific diesel train, the Burlington "Zephyr" and others operated on special diesel fuels served to revive the intimations and fears of several years ago as to the ultimate replacement of the gasoline motor by diesel engines in even the passenger car field. How-

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ever, an analysis presented at the American Petroleum Institute's annual meeting by a competent authority indicated that economic and design limitations might well bar broad commercial application to smaller than 5-ton units. The problem of preparing acceptable diesel fuels came in for considerable study and discussion, although specifications of the ideal fuel have not as yet been drawn. The growing importance of this outlet for the refiners' products is evidenced by an increase of over 200 per cent in total horsepower of diesel motors manufactured in 1934 over 1933, with predictions of over 1,000,000 hp. to be made in 1935, as compared with 750,000 for 1934 and 250,000 in 1933.

A noteworthy feat in economic engineering, and a new experience for the refining industry, was the general control of gasoline production throughout the country during the year, under Petroleum Code Authority, through the Planning and Coordination Committee and the Petroleum Administrator. Procedure was the allocation to and through district agencies to individual plants of a predetermined national requirement. Production of gasoline was so controlled as to reduce stocks at the end of the high consuming season to a point many millions of barrels below the amounts that otherwise would have prevailed. While observance of manufacturing allocation limitations was effective in the main, unfortunately there was sufficient disregard as to both crude oil and gasoline production (largely in the East Texas field area) to offset the beneficial effect and prevent the improvement in prices which removal of the economic pressure of excessive stocks was expected to bring about; in consequence of which refiners "playing the game" operated for most of the year at a loss. However, during the last quarter new state legislation and more vigorous action on the part of both Federal and state authorities looking toward controlling and curbing illicit gasoline and crude production in the East Texas area give promise that during 1935 this bearish and disturbing factor will be largely eliminated, and refiners able to have a price for their gasoline that will permit them to operate at a fair profit. If this does occur there will undoubtedly be ushered in during 1935 an era of engineering activity in the form of new developments and modernizing of old equipment on a scale lacking for several years past.

Expanded use of various solvents in the extraction and refining of lubricating oil is notable. General interest has been broadened to include as well the commercial aspect of dewaxing and deasphaltizing. Plants having a combined daily capacity of approximately 30,000 bbl. of finished oils were completed during the year, and others are under construction or contemplated. The broad operating experience is bringing to light, as was to be expected, many improvements in design and operation of solvent plants, tending both to simplify later installations and increase operating efficiencies. Many refiners are still undecided as to their course. It remains to be seen how the demand will be influenced by advertising campaigns of those now using solvent processes commercially; how strongly demand will respond to arguments of high viscosity index, negligible carbon residue, etc., in view of the fact that the public generally has had little to complain of in lubricating oils already available. A competitive situation similar to the octane race may be in the making.

Another noteworthy development is the increasing trend in automobile motor manufacturing toward design of motors requiring lower viscosity lubricants. The public is being quickly educated along this line by specifications and recommendations of the motor manufacturers, and the popular prejudice against "thin looking" oil, which in the past has stopped many an attempt to market lubricants of lower viscosity, is disappearing rapidly. An economic effect of this tendency will be to increase the requirements for the neutral oil fractions and decrease to some extent the demand for the highly viscous bright stock components. This effect will have to be taken into consideration in future lubricating-oil manufacturing plans and design. The increasing horsepower, speed and bearing pressure of automotive equipment are making greater demands upon lubricating oils, and are largely responsible for the trend to lower viscosity. The same factors were also influential in promoting the greater general interest in the subject of lubricating compounding agents for the improvement of the oiliness characteristic, bearing-load capacity and general stability of the petroleum lubricants used. While the subject itself is not new, the field having been rather exclusively occupied for many years, the widespread interest is evidenced by patent literature, general discussions and the fact that such organizations as the American Society for Testing Materials and the Society of Automotive Engineers are now studying extreme pressure and oiliness agents.

Reports of various refining committee activities presented at the American Petroleum Institute annual meeting indicated good, and in some cases more than normal, progress along the lines of standardization of refinery equipment, fire prevention, accident prevention, control of refinery waste, prevention and control of corrosion, etc. A great deal of quiet, persistent and intelligent work is being accomplished by these committees, work that seldom reaches the headline stage but is made available to the industry by suitable reports and bulletins.

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